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Wish you a Very Happy & Prosperous New Year 2020

Senior dignitaries during Inauguration of International Colloquium on 21 November 2019 at New Delhi
Mr. S.K.G. Rahate, Addl. Secretary, Govt. of India, Ministry of Power (in the middle)
(to his right) Mr. I.S. Jha, Hon'ble Member, CERC & President CIGRE-India; Mr. Prakash S. Mhaske, Chairperson, Central Electricity Authority & Ex Officio Secretary to Govt. of India and Mr. K. Sreekant, Chairman & Managing Director, POWERGRID.
(to his left) Mr. V.K. Kanjlia, Secretary, CIGRE-India; Dr. Konstantin, Honorary Member, CIGRE Paris and Former Chairperson of CIGRE Study Committee on Overhead Lines and Mr. P.P. Wahi, Director, CIGRE-India

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EDITOR'S NOTE

V.K. Kanjlia
Secretary & Treasurer
CIGRE India

CIGRE the International Council on Large Electric Systems founded in 1921, is leading worldwide Organization on Electric Power Systems, covering technical, economic, environmental, organisational and regulatory aspects. It deals with all the main themes of electricity. CIGRE is the unique worldwide organization of its kind - 14,000 equivalent members in around 90 countries. CIGRE is focused on practical technical applications. The main aim of CIGRE is to facilitate and develop the exchange of engineering knowledge and information, between engineering personnel and technical specialists in all countries as regards generation and high voltage transmission of electricity. CIGRE achieves its objective through the 16 Study Committees, each consisting of about 30 members from different countries. It is a matter of pride for India that we are representing in all the 16 Study Committee of CIGRE.

Besides National Committees in about 60 Countries CIGRE has also constituted its regional chapters in the world. The chapter created for Asia is named as CIGRE-AORC (Asia Oceans Regional Council). CIGRE-AORC is a forum for sharing experience and knowledge regarding pertinent technical issues particularly those affecting power systems in the Asia-Oceana Region. The countries from Asia Oceana Region, who are associated with the forum are Australia, China, Cambodia, Gulf Cooperative Council, Hong Kong, India, Indonesia, Iran, Jordan, Japan, Korea, Malaysia, New Zealand, Taiwan and Thailand.

It is a matter of great honour for India that CIGRE AORC has been chaired by India during 2016-2018. Dr. Subir Sen, ED, POWERGRID was Chairman and Shri P.P. Wahi, Secretary of CIGRE AORC for two year during 2016-18.

CIGRE (India) has been in the administrative Council of CIGRE since 1970 and got seat in Steering Committee in 2018. CIGRE India functions as the National Committee, for CIGRE HQ (Paris). The CIGRE (India) coordinates interest of Indian members; organises National Study Committee (NSC) meetings. It recommends appropriate persons for CIGRE Study Committees. The National representatives are instrumental in providing feed back to CIGRE Study Committees at Paris.

The aims and objectives for which the committee, i.e., CIGRE (India), is constituted, is to implement and promote objectives of the International Council on Large Electric Systems (CIGRE) and accelerate its activities, which include the interchange of technical knowledge and information between all countries in the general fields of electricity generation transmission at high voltage and distribution etc.

All-out efforts are being made to increase the CIGRE membership and activities in India. CIGRE India has regularly been making efforts to invite various CIGRE study committees and their working groups to hold their meeting in India. We in the recent past have already hosted SC D2 on Information and telecommunication in 2013; SC B4 on HVDC - in 2015 and SC B1 on HV Insulated cables in 2017 in India. In the Year 2019 we have hosted four Study Committees SC A1 on Rotating Electrical Machines in Sept. 2019 & SC A2; SC B2 & SC D1 on Transformers, Overhead Lines and Materials & test techniques respectively in Nov. 2019. This is done with the aim to provide opportunities to professional to exchange & share views / knowledge with international experts. For the year 2021 we have already got approval from CIGRE to host study Committee B5 on Power System protection & SC A3 on high voltage equipment's. There was excellent participation from India in CIGRE session 2018 at Paris. Total 22 papers were presented and more than 150 officers from India including CEOs & Sr. Officers from various PSUs, State Electricity Corporation and various Regulatory Commissions participated in CIGRE session 2018 besides six exhibitors.

For CIGRE Session 2020, CIGRE India received 240 Abstract for consideration. Out of the 45 Abstracts were recommended to CIGRE HQ for their consideration 37 abstracts have accepted.

The Membership of CIGRE from India is also on the rise and in the year 2018 we achieved membership count to 827 Nos. and the same was maintained for 2019 also.

We are bringing out this Journal on half yearly basis. The last issue was published in the month of July 2019.

This issue covers the informative and useful technical articles and statistical data on the subject.

I am thankful to the Governing Council and the Technical Committee of CIGRE-India for their valuable time and guidance, but for which, it would not have been possible to achieve the above significant progress, appreciated by CIGRE HQ Paris.

I am also thankful to all the senior experts from India and abroad and also to one and all who have supported in the past to realize the goal set forth for CIGRE India and expect the similar support in future too.

V.K. Kanjlia
Secretary & Treasurer CIGRE India

Inadequate Earthing (Grounding) in Distribution Sector – Root Cause for Many Maladies

Dr. Rajesh Kumar Arora
Delhi Transco Limited

ABSTRACT

Earthing facilitates the efficient and quick operation of protective relays in case of any earth fault and provides safety to costly equipments as well as working personnel. This paper presents the basics, types and purposes of earthing system. A low voltage (LV) distribution system may be identified according to its earthing system. These are defined using the five letters T (Direct connection to earth), N (Neutral), C (Combined), S (Separate) and I (Isolated from earth). Paper provides information about applications and importance of different system of earthing like TT, IT, TN-S, TN-C, TN-C-S. The paper also highlights the importance of grounding in the distribution system.

Keywords : *Earthing (Grounding), Low Voltage Distribution System, System Earthing, Protective Earth (PE), PEN Conductor, Step & Touch Potential, GPR.*

1. INTRODUCTION

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground.

Every building, equipments, power plants, substation facilities included in electricity require earthing (grounding), either directly or through grounding system, the main objective of doing earthing in electrical network is safety.

But when the neutral for any system is not connected with the earth then it will be known as electrical system without earthing as depicted in Fig. 1.

Mostly, the galvanised iron is used for the earthing. The earthing provides the simple path to the leakage current and fault current in the system. The short-circuit current of the equipment passes to the earth which is assumed to have zero potential. Thus, protects the system equipments and personnel working with these equipment from damage as well as shock current as shown in Fig. 2.

Earthing is not likely to reduce the total magnitude of over voltages produce by lightening or switching surges, it can however mitigate the possibilities of excessive voltage stress on the phase to ground insulation of particular phase.

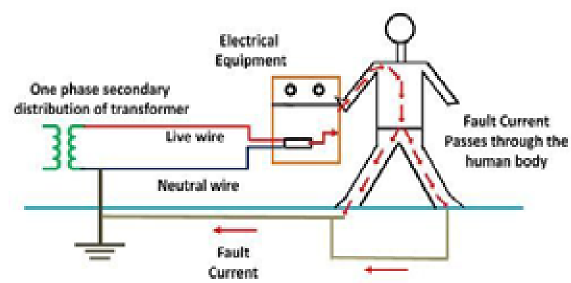

Fig. 1 : Electrical System without Earthing

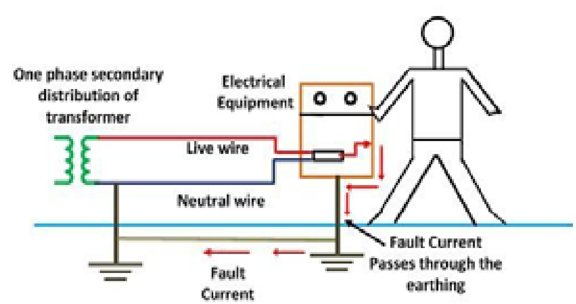

Fig. 2 : Electrical System with Earthing

The system earth resistance should be such that which any fault occurs against which earthing is designed to give protection, the protective gear will operate to make the faulty main or plant harmless. In most cases, such operation involves isolation of the faulty main or plant, for example by circuit breaker or fuses.

Distribution Transformer is the key element in the distribution system where the neutral point of the system is grounded. This transformer with the help of distribution lines distributes the electricity to the consumers. The actual picture of distribution transformer and role of

DT in distribution system are shown in Figure 3 and 4 respectively.

Fig. 3 : Distribution Transformer

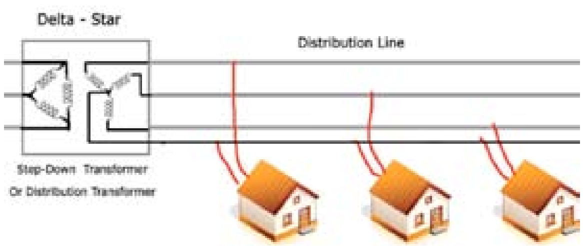

Fig. 4 : Role of Distribution Transformer in Distribution Network

2. TYPES OF ELECTRICAL EARTHING (GROUNDING)

The electrical equipment mainly consists of two non-current carrying parts. These parts are neutral of the system or frame / support structure of the electrical equipment. From the earthing of these two non-current carrying parts of the electrical system, earthing can be classified into two types:

1. Neutral Earthing
2. Equipment Earthing

2.1 Neutral Earthing (System Grounding)

In neutral earthing, the neutral of the system is directly connected to earth with the help of some metallic conducting wire. The neutral earthing is also called the system earthing. Such type of earthing is mostly provided to the system which has star winding. For example, the neutral earthing is provided in the generator, transformer, motor etc as shown in Fig 5.

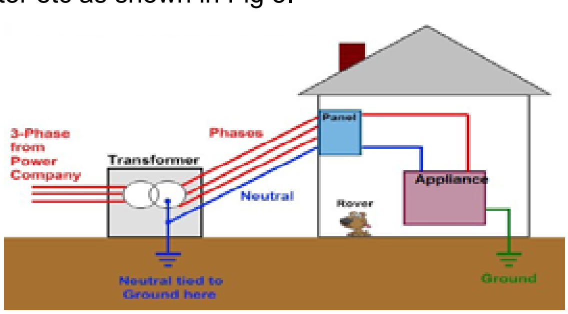

Fig. 5 : Neutral and Equipment Earthing

2.2 Equipment Earthing (Grounding)

Such type of earthing is provided to the electrical equipment. The non-current carrying part of the equipment like their metallic frame is connected to the earth by the help of the conducting wire as shown in Fig. 5. If any fault occurs in the apparatus, the short-circuit current to pass the earth by the help of wire. Thus, protect the system from damage.

3. IMPORTANCE / PURPOSE OF EARTHING

The main objective / purpose of earthing are:

- To Protect the workers who regularly come in contact with electrical devices that might give them a shock.
- To keep the voltage of the device constant in the healthy phase in case of single of single phase to ground fault.
- A good grounding path which has a low impedance value ensure that faults in the electrical path are cleared quickly. If the faults stay within the system for a long time, they can pose a serious threat to the stability of the system.
- Many modern electronic devices generate a form of 'electrical noise' that can cause damage to the device and reduce its efficiency, unless the device is property grounded.
- Surge protection device function better with the help of proper grounding.
- Malfunctioning electric devices often leak electricity, which has the potential to start a fire if not redirected safely.

The main objective of grounding electrical systems is to provide a suitably low resistance path for the discharge of fault current which ultimately provide safety to working personnel and costly installed equipments in the substation. The flow of heavy fault current results in rise of potential in the substation area and with respect to remote ground. There is need to ensure that the ground potential rise, and touch and step voltages are within permissible limits.

4. ROLE OF ADEQUATE EARTHING IN PREVENTION OF HAZARDS

In order to understand the role of adequate earthing design, abstract of IS 3043 are given below:

4.1 Basic Objective of System Earthing

- Earthing of system is designed primarily to preserve the security of the system by ensuring that the potential on each conductor is restricted to such a value that is consistent with the level of insulation applied.
- From the point of view of safety, it is equally important that earthing should ensure efficient and fast operation of protective gear in the case of earth faults.

- The system earth-resistance should be such that, when any fault occurs against which earthing is designed to give protection, the protective gear will operate to make the faulty main or plant harmless. In most cases, such operation involves isolation of the faulty main or plant, for example, by circuit-breakers or fuses.

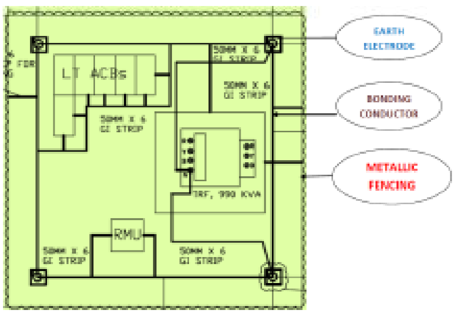

Fig. 6 : Earthing Layout of Distribution Transformer

4.2 Equipment Earthing

The basic objectives of equipment grounding are:

- to ensure freedom from dangerous electric shock voltages exposure to persons in the area;
- to provide current carrying capability, both in magnitude and duration, adequate to accept the ground fault current permitted by the over current protective system without creating a fire or explosive hazard to building or contents; and
- to contribute to better performance of the electrical system.

Neutral and equipment earthing of distribution transformer are shown in Figure 6.

Further, let us try to understand the above concepts as follow :

Voltage Exposure *:* When there is unintentional contact between an energized electric conductor and the metal frame or structure that encloses it or is adjacent, the frame or structure tends to become energized to the same voltage level as exists on the energized conductor. To avoid this appearance of this dangerous, exposed shock hazard voltage, the equipment grounding conductor must present a low impedance path from the stricken frame to the zero potential ground junction. The impedance should also be sufficiently low enough to accept the full magnitude of the line-to-ground fault current without creating an impedance voltage drop large enough to be dangerous.

Avoidance of Thermal Distress *:* The earthing conductor must also function to conduct the full ground fault current (both magnitude and duration) without excessively raising the temperature of the earthing conductor or causing the expulsion of arcs and sparks that could initiate a fire or explosion. The total impedance of the fault circuit including the grounding conductor should also permit the required current amplitude to cause operation of the protective system.

Preservation of System Performance *:* The earthing conductor must return the ground fault current on a circuit without introducing enough additional impedance to an extent that would impair the operating performance of the over current protective device, that is, a higher than necessary ground-circuit impedance would be acceptable if there is no impairment of the performance characteristics of the protective system.

Picture of fire of distribution transformer is shown in Figure 7.

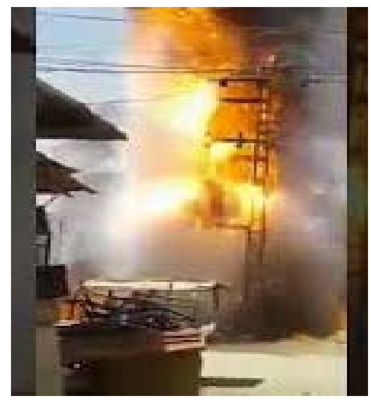

Fig. 7 : Distribution Transformer on Fire

5. UNGROUNDED AND GROUNDED NEUTRAL SYSTEM

Generally earthing of neutral point of the transformer and the generator is called the system earthing. Now, if the neutral point for any system is connected to the earth then it will be called grounded system.

But when the neutral for any system is not connected with the earth then it will be called ungrounded system as shown in Figure 8. Connecting the neutral point to the earth through a resistance means resistance earthing and reactance earthing means connecting the neutral point to the earth through a resistance. When the neutral point connected to the earth directly it will call solidly grounded as shown in Figure 9.

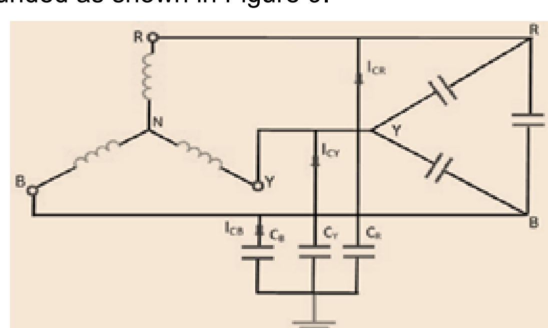

Fig. 8 : Ungrounded Neutral System

5.1 Disadvantage of Ungrounded Neutral Earthing System

- **System Voltage Increase:** When the earth fault occurs in line then the potential of the faulty phase becomes equal to ground potential. However, the voltages of the two remaining healthy phases rise from their normal phase voltages to full line value. This may result in insulation breakdown.
- **Protection Complicacy:** In this system earth fault is not easy to sense and troubleshoot will become complicated.
- **Arcing Ground:** Sudden temporary fault can caused by failing of a branch creates an arc between the overload line and the ground. Arc extinguished and can re strike in a repeated regular manner. This is called arcing ground.
- **Static Induced Voltage:** Over voltage due to the static induced charges are not conducted to the earth.

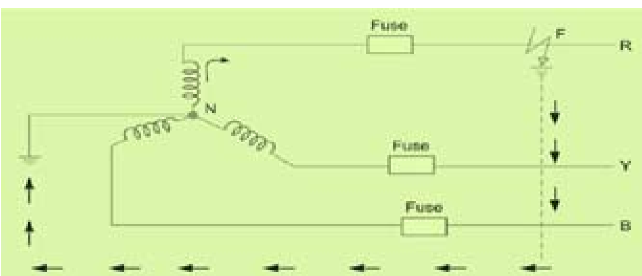

Fig. 9 : Grounded Neutral System

5.2 Advantage of Grounded Neutral Earthing System

- **The System Voltage Will not Increase in Case of Ground Fault:** When the healthy line of a grounded system i.e earthed the voltage of the healthy line will not increase w.r.t. earth as in the case of ungrounded earthing system.
- **Arcing Grounds are Eliminated:** If the neutral point of the system is earthed then the distribute capacitive current from the lines to earth will neutralized by the current from the neutral point to earth and the arcing grounds will eliminated.
- It will be a **stable neutral point**.
- Life of the **insulation** will increase.
- It will give general **safety** to personnel and the equipments due to operation of the **fuses**.
- Over voltage due to sudden lightning will discharged to the earth.
- Earth fault relaying will relatively simple.

6. EARTHING SYSTEM FOR LV NETWORK

A low voltage (LV) distribution system may be identified according to its earthing system. These are defined using the five letters T (direct connection to earth), N (neutral), C (combined), S (separate) and I (isolated from earth). The first letter denotes how the transformer neutral (supply source) is earthed while the second letter denotes how the metal work of an installation (frame) is earthed. The third and fourth letters indicate the functions of neutral and protective conductors respectively.

There are three possible configurations.

TN: transformer neutral earthed, frame connected to neutral.

- The TN system includes three sub-systems: TN-C, TN-S and TN-C-S
- TT: transformer neutral earthed and frame earthed.
- IT: unearthed transformer neutral, earthed frame.

6.1 TN Earthing System

In a TN earthing system, the supply source (transformer neutral) is directly connected to earth with one or more conductors and all exposed conductive parts of an installation are connected to the neutral or protective earth conductor. The three sub-systems in TN earthing system are described below with their key characteristics.

6.1.1 *TN-C Earthing System*

TN-C system has the following features:

- Neutral and protective functions are combined in a single conductor throughout the system. (PEN - Protective Earthed Neutral).
- The supply source is directly connected to earth and all exposed conductive parts of an installation are connected to the PEN conductor as shown in Fig. 10.

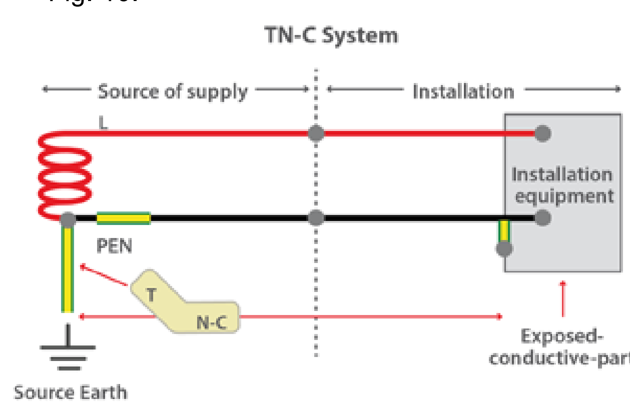

Fig. 10 : TN-C Earthing System

Advantages of TN-C Earthing System

- Earth fault loop impedance of TN-C earthing system is low.
- It does not requires earth electrode at site.
- It is economical.

Disadvantages of the TN-C Earthing System

- TN-C earthing system is least safest as compared to other earthing systems
- TN-C system is less effective for Electromagnetic Compatibility (EMC) problems.
- A fault in the LV network may cause touch voltages at other LV customers.

6.1.2 *TN-S Earthing System*

TN-S System has the following features:

- A TN-S System has separate neutral and protective conductors throughout the system.
- The supply source is directly connected to earth. All exposed conductive parts of an installation are connected to a protective conductor (PE) via the main earthing terminal of the installation as shown in Fig. 11.

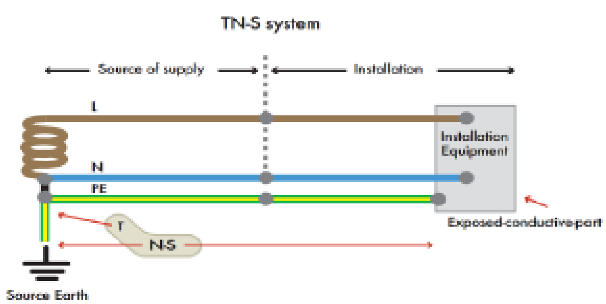

Fig 11 (a) : TN-S Earthing System

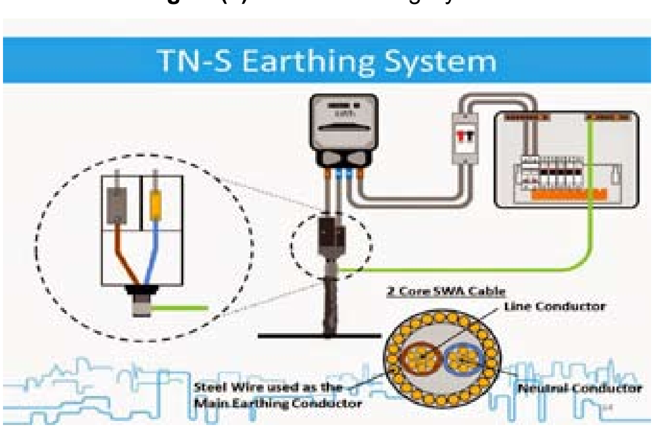

Fig. 11 (b) : TN-S Earthing System

Advantages of TN-S Earthing System

- Earth fault loop impedance is low
- TN-S is the safest system
- Electromagnetic interference is low
- It does not requires earth electrode at site
- TN-S earthing system could work with simple over current protection.

Disadvantages of the TN-S Earthing System

- Low power factor (high inductance of long cable)
- Requires extra equal potential bonding.
- On occurrence of an insulation fault, the short-circuit current is high and may cause damage to equipment or electromagnetic disturbance.

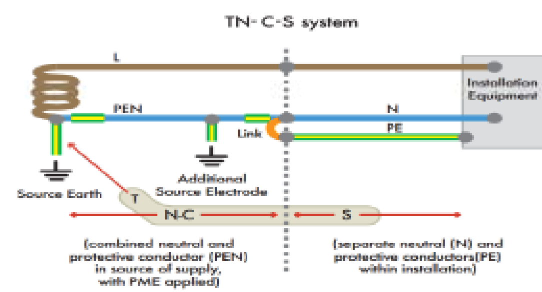

Fig. 12 : TN-C-S Earthing System

6.1.3 *TN-C-S Earthing System*

TN-C-S earthing system has the following features:

- Neutral and protective functions are combined in a single conductor in a part of the TN-C-S system. The supply is TN-C and the arrangement in the installation is TN-S as depicted in Fig. 12.
- Use of a TN-S downstream from a TN-C.
- All exposed conductive parts of an installation are connected to the PEN conductor via the main earthing terminal and the neutral terminal, these terminals being linked together.

This type of distribution is known also as protective multiple earthing and the PEN conductor is referred to as the combined neutral and earth (CNE) conductor. The supply system PEN conductor is earthed at several points and an earth electrode may be necessary at or near a consumer's installation.

Advantages of TN-C-S Earthing System

- This system is a safe system
- This system is less expensive

Disadvantages of the TN-C-S Earthing System

In the TN-C-S system, the TN-C (4 wires) system must never be used downstream of the TN-S (5 wires) system, since any accidental interruption in the neutral on the upstream part would lead to an interruption in the protective conductor in the downstream part and therefore a danger.

6.2 TT Earthing System

In this system, the supply source has a direct connection to earth. All exposed conductive parts of an installation also are connected to an earth electrode that is electrically independent of the source earth as shown in Fig. 13. The fault loop impedance is higher, and unless the electrode impedance is very low indeed.

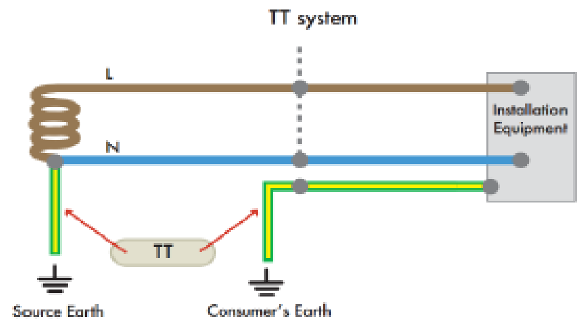

Fig. 13 : TT Earthing System

Advantages of TT System

- No risk of failure and suitable for premises where all AC power circuits are residual current device (RCD) protected.
- Faults in the LV and MV grid do not migrate to other customers in the LV grid.
- Simple earthing of the installation and the easiest to implement.

Disadvantages of the TT Earthing System

- Each customer needs to install and maintain its own ground electrode. Safety and protection depends on the customer, thus complete reliability is not assured.
- High over voltages may occur between all live parts and between live parts and PE conductor.
- Possible overvoltage stress on equipment insulation of the installation.

6.3 IT System Earthing

In this system, the supply source is either connected to earth through deliberately introduced high earthing impedance (Impedance earthed IT system) or is isolated from earth. All exposed conductive parts of an installation are connected to an earth electrode as shown in Fig. 14.

The conductive parts including metal body of the installations are connected to earthed through one or more local earth electrodes. These local electrodes do not have any direct connection to the source. It is pertinent to mention here that single phase IT system shown in Fig. 14 is not used in India.

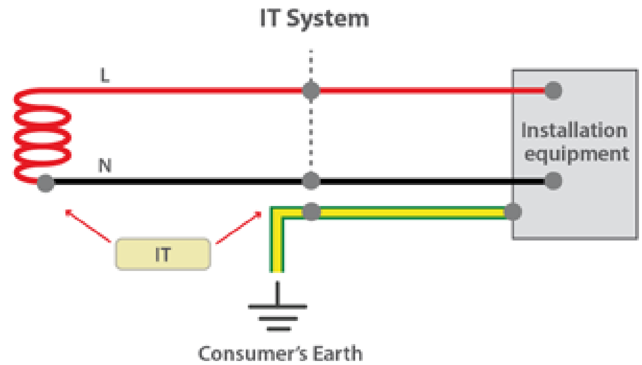

Fig. 14 (a) : IT Earthing System

Advantages of IT System

The main advantages of IT system are the followings;

- It improves the energy availability: this is interesting for applications where a loss of electricity supply can cause a risk to people (in hospitals for example), or a financial risk (for some process in industry).
- It can also eliminate the risks of fire or explosions in case of insulation fault, as the faulty current is very low.
- It will increase electrical device life time, as faulty current is low, it causes less stress on the equipment.
- Finally, it is possible to do preventive maintenance on the IT installation. Through the permanent insulation monitor device, we can detect insulation drops before they become insulation faults.

Disadvantage of IT System

- This system experience repeated arcing grounds.
- Insulation failure occurs during single phase to ground faults.
- Earth fault protection for unearthed system is difficult.
- Voltage due to lightning surges do not find path to earth.

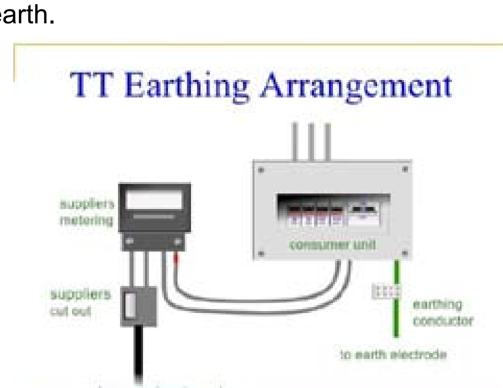

Fig. 14 (b) : IT Earthing System

7. COMPARISON OF ALL EARTHING SYSTEMS

Comparison of all earthing systems based on earth fault loop impedance, RCD preferred, need earth electrode at site, PE conductor cost, etc. has been carried out as follows (Table 1):

Table 1 : Comparison of all Earthing Systems

EARTHING SYSTEM CONDITIONS	TN-C	TN-S	TN-C-S	TT	IT
1. Earth Fault Loop Impedance (EFLI)	Low	Low	Low	High	Highest
2. RCD Preference	No	Optional	Optional	Yes	N.A.
3. Need of Earth Electrode at Site	No	No	Optional	Yes	Yes
4. PE Conductor Cost	Least	Highest	High	Low	Low
5. Risk of Broken Neutral	Highest	High	High	No	No
6. Safety	Least safe	Safest	Safe	Safe	Less safe
7. Electromagnetic Interference	High	Low	Low	Least	Least
8. Safety risks	Broken neutral	Broken Neutral	Broken neutral	High loop Impedance (step voltages)	Double fault, over voltage

We may also refer the Figure 15 to understand the protection system involved in three types of earthing system.

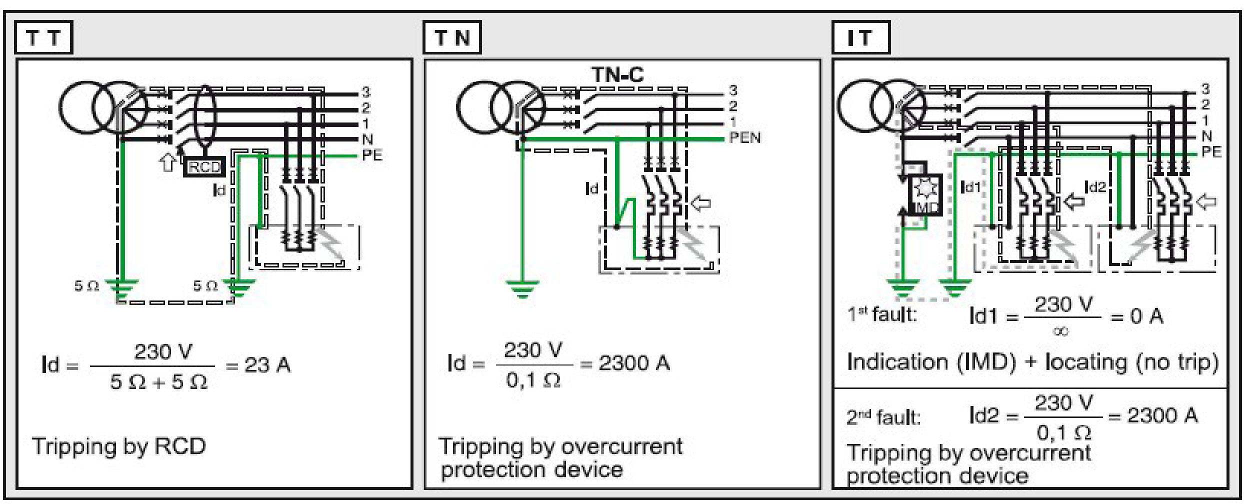

Fig. 15 : Protection Tripping in Different Earthing Systems

8. CONCEPT OF GPR STEP AND TOUCH POTENTIAL

In electrical engineering, earth potential rise (EPR) also called ground potential rise (GPR) occurs when a large current flows to earth through an earth grid impedance. The potential relative to a distant point on the Earth is highest at the point where current enters the ground, and declines with distance from the source. Ground potential rise is a concern in the design of electrical substations because the high potential may be a hazard to people or equipment.

The change of voltage over distance (potential gradient) may be so high that a person could be injured due to the voltage developed between two feet, or between the ground on which the person is standing and a metal object. Any conducting object connected to the substation earth ground, such as telephone wires, rails, fences, or metallic piping, may also be energized at the ground potential in the substation. This transferred potential is a hazard to people and equipment outside the substation. Various dangerous potential which may be encountered in any substation are depicted in Figure 16.

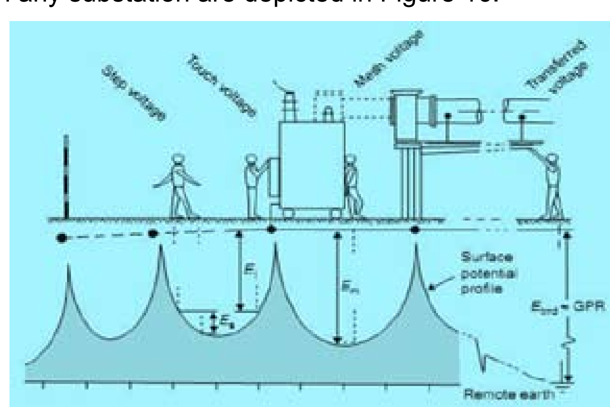

Fig. 16 : Various Dangerous Potentials during Fault

Many factors determine the level of hazard, including: available fault current, soil type, soil moisture, temperature, underlying rock layers, and clearing time to interrupt a fault.

An EPR event at a site such as an electrical distribution substation may expose personnel, users or structures to hazardous voltages. (Figure 17)

An engineering analysis of the power system under fault conditions can be used to determine whether or not hazardous step and touch voltages will develop. The result of this analysis can show the need for protective measures and can guide the selection of appropriate precautions.

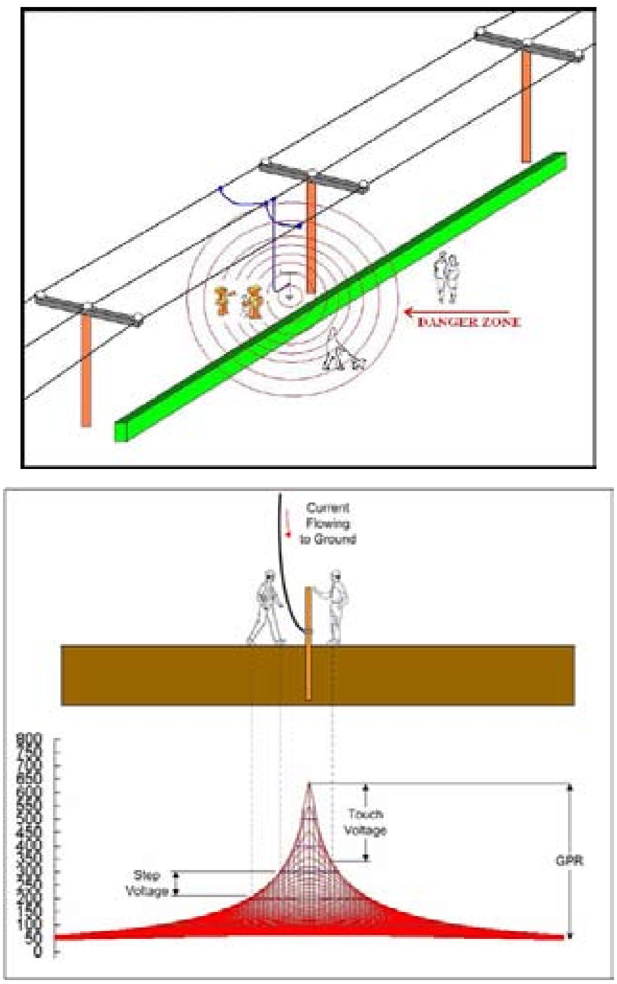

Fig. 17 : Concept of ESP and Danger of Touch & Step Potential

- **Step Potential :** Step potential is the step voltage between the feet of a person standing near an energized grounded object. It is equal to the difference in voltage, given by the voltage distribution curve, between two points at different distances from the electrode. A person could be at risk of injury during a fault simply by standing near the grounding point. (Figure 18)

- **Touch Potential :** Touch potential is the touch voltage between the energized object and the feet of a person in contact with the object. It is equal to the difference in voltage between the object and a point some distance away. The touch potential or touch voltage could be nearly the full voltage across the grounded object if that object is grounded at a point remote from the place where the person is in contact with it. (Figure 18)

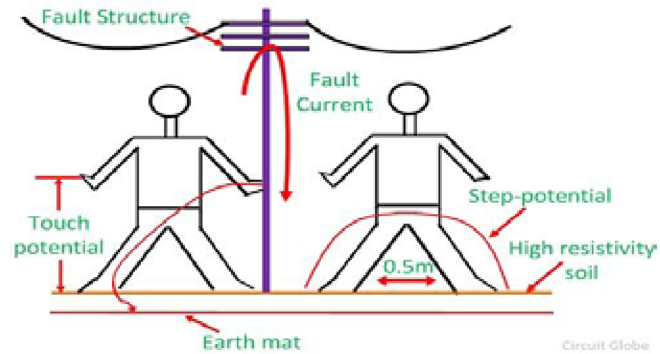

Fig. 18 : Illustrations of Step & Touch Potential

The more current that is pumped into the ground, the greater the hazard. Fault clearing time is an important factor to consider as well. The more time it takes the electric utility company to clear the fault, the more likely it is for a given level of current to cause the human heart to fibrillate.

A few engineers believe that Fibrillation Current for Step Potentials must be far greater than Touch Potentials, as current will not pass through any vital organs in the former case. This is not always true as personnel that receive a shock due to Step Potentials may fall to the ground, only to be hit again, before they can get up, when the automatic re-closers activate.

The impact of step and touch potential may become the cause of deaths of many living stock (animals) also as depicted by Figure 19 .

Fig. 19 : Electrocution of Elephants in the Field

How to Control Hazardous Potentials: Several methods may be used to protect employees from hazardous ground-potential gradients, including equipotential zones, insulating equipment, and restricted work areas.

1. The creation of an equipotential zone will protect a worker standing within it from hazardous step and touch voltages. Such a zone can be produced through the use of a metal mat connected to the grounded object. Usually this metal mat (or ground mesh) is connected to buried ground rods to increase contact with the earth and effectively reduce grid impedance. In some cases, a grounding grid can be used to equalize the voltage within the grid. Equipotential zones will not, however, protect employees who are either wholly or partially outside the protected area. Bonding conductive objects in the immediate work area can also be used to minimize the voltage between the objects and between each object and ground. (Bonding an object outside the work area can increase the touch voltage to that object in some cases, however.)

2. The use of insulating personal protective equipment, such as rubber gloves, can protect employees handling grounded equipment and conductors from hazardous touch voltages. The insulating equipment must be rated for the highest voltage that can be impressed on the grounded objects under fault conditions (rather than for the full system voltage).

3. Workers may be protected from hazardous step or touch voltages by prohibiting access to areas where dangerous voltages may occur, such as within substation boundaries or areas near transmission towers. Workers required to handle conductors or equipment connected to a grounding system may require protective gloves or other measures to protect them from accidentally energized conductors.

In electrical substations, the surface may be covered with a high-resistivity layer of crushed stone or asphalt. The surface layer provides a high resistance between feet and the ground grid, and is an effective method to reduce the step and touch voltage hazard.

9. ELECTROCUTION TRIANGLE & SAFETY EFFECTIVENESS PYRAMID

In substation whenever fault occurs resulting in the flow of heavy current in the grounding system which may pose problems of GPR, step and touch potential in the vicinity. If the grounding system is not adequate may result in the electrocution of the working personal or passerby. The electrocution triangle and effectiveness of electrical safety in any system are depicted in Fig. 20 :

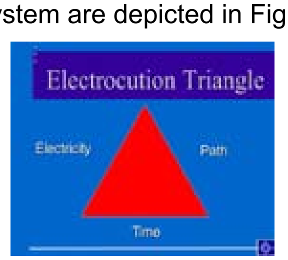

Fig. 20 : Accident Triangle & Pyramid of Prevention of Accidents

The accepted minimum value of body resistance is 500 ohms for electric shock hazard analysis. Although the resistance between hands with dry skin can range from 5,000 to 50,000 ohms, punctured skin reduces the body resistance to about that of salt water which is very low. Voltages above 240 volts readily penetrate dry skin, leaving a small, deep burn.

The maximum safe body current for short periods of time is given by Dalziel's equation of IEEE-80 and is an inverse function of time. Higher currents are permitted for shorter periods of time. Shock durations, or human exposure times for temporary personal protective grounding applications are determined from typical 50/60 Hz power system fault clearing time.

The fault clearing time is based on typical protective relaying and circuit breaker operating time. Plants and switchyards generally are protected by high-speed current differential relays with faster operating times compared to transmission lines employing zone distance relaying.

10. CONCLUSION

When a fault occurs in the distribution system, the current will enter the earth. This heavy fault current will develop hazard potential around earth electrode due to distribution of varying resistivity in the soil near earth electrode. The voltage drop in the soil surrounding the grounding system can present hazards i.e. Step and touch voltage for personnel standing in the vicinity of the grounding system.

Adequate designing of grounding system will help in mitigating or eliminating fire and accident hazard.

It is very important for an electrical engineer to understand the fundamental and importance of grounding system for the safety of staff and installed equipments in the network. Soil resistivity and proper measurement of resistivity & interpretation of results are prime factors for accurate designing of grounding system. Other important factors are fault current, grid current, surface material resistivity and type of protection system play crucial roles in the effective designing of grounding system of substation.

From the information provided in this paper it can be concluded that for LV system

- An improper grounding results in higher potential being created in the equipment that can damage equipment and pose safety threat to working personnel.
- It can delay in clearing of faults that will result in insufficient current flow.
- The dangers of a fire caused by leaking electricity are increased exponentially
- It can cause reduction in the operational efficiency of the machine.

Besides above, the choice of earthing system depends on the priority given to many aspects mentioned in Table 1 by the relevant distribution company and regulatory authority of county.

REFERENCES

1. IEEE Std. 80-2013, IEEE Guide for Safety in AC Substation Grounding, New York, NY: IEEE
2. IEEE: 81: 1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
3. Manual on," Grounding of A C Power Systems," Publication No 302, C.B.I.P. New Delhi, Oct. 2007
4. I.S.3043 Indian Standard Code of Practice for Grounding.
5. CEA 'Measures relating to Safety and Electric Supply' and 'Technical Standards for Construction of Electrical Plants and Electrical Lines and Connection to Grid under Regulations 2010.
6. Notes of Zero Sequence Earthing
7. R Kumar, K Bansal, D K Saini, I P S Paul, "Importance and Need of Accurate Modelling of Soil of High Voltage Substation for Optimal Designing of Grounding System", IJEC, 7(1), pp. 29-44, 2015.
8. Books of Power System by V K Mehta and C L Wadhwa.

BIOGRAPHICAL DETAILS OF THE AUTHOR

Dr. Rajesh Kumar Arora obtained the B. Tech. & Master of Engineering (ME) degrees in Electrical Engineering from Delhi College of Engineering, University of Delhi, India in 1999 and 2003 respectively. He completed his Ph.D. in grounding system design from UPES, Dehradun. He is also certified Energy Manager and Auditor. He has worked in 400 kV and 220 kV Substation for more than 14 years in Delhi Transco Limited (DTL). He has also worked as Deputy Director (Transmission and Distribution) in Delhi Electricity Regulatory Commission (DERC) for 03 years and 06 months. He has also given his contribution in the OS department of DTL for more than 2 years and rendered his services in the SLDC of Delhi Transco Limited (DTL) also. Presently he is working in OS (Operation Services) department of DTL. His research interests include high voltage technology, grounding system, protection system, computer application and power distribution automation.

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Transformer Bushings: Current Technology Trends, Developments & it's Relevance in Monitoring of Bushings in Service

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ABSTRACT

Transformer Bushings are expected to be highly reliable components of Transformers. In the event of Failure of Transformer Bushings, usually the result is downtime of several weeks of a power transformer accompanied by financial losses & urgency to restore the system at the earliest. Majority of the Bushings in service (for past many years) are Bushings with OIP (Oil Impregnated Paper) Insulation System. In India, major usage of RIP (Resin Impregnated Paper) Insulated Bushings commenced in 2011-12 & recently in 2018 RIS (Resin Impregnated Synthetics) Insulated Bushings have been also introduced in Indian Grid. OIP Bushings are well established up to 800 kV & RIP Bushings are now in use up to 420 kV and RIS Bushings are reported to be available up to 245 kV. This paper reviews the Current Technology Trends.

In view of Various Insulation Technologies in use, it is essential to understand technical aspects of Insulation Degradation Mechanism and their effects on Service Behaviour of Bushings. This paper describes these aspects in detail. Tan Delta has been considered as a vital health monitoring parameter for OIP Bushings & different utilities have adopted stringent limits for Tan Delta (when compared with IEC Limits of 0.007). Data based evaluation & trend analysis of increase in Tan Delta gives a preliminary clue about Bushing Health, however this needs to be supplemented by DGA Analysis of Oil Sample. This paper describes it in detail.

For dry RIP & RIS Bushings, however Capacitance and Partial Discharges Monitoring reveals the information about health of these Bushings. Tan Delta reveals status of pre-commissioning health. This paper describes in detail, associated technical aspects to help identify more relevant/reliable and safe practices for condition monitoring and interpretation of tests in case of dry RIP/RIS bushing fleet. Described in detail are the difference in Tan Delta behaviour between OIP Bushings & RIP Bushings. The experimentation results of Temperature Dependence of Tan Delta of OIP & RIP are shared in this paper. Various site conditions which influence the Tan Delta measurements & the precautions to be taken to prevent wrong conclusions are described .

Keywords : *Transformer, Transformer Bushings, Condenser bushings, OIP, RIP, RIS, Tan Delta, Bushing condition monitoring.*

INSULATION SYSTEMS IN USE FOR BUSHINGS

OIP (Oil Impregnated Paper): It's use is reported since 1950 & OIP Bushing manufacturing Technology is now well established for past 70 years up to 800 kV rating. Majority of Bushings in service still have OIP as insulation. RIP (Resin Impregnated Paper): Truly a Solid Insulation System. The Popular RIP Bushings in the market are free of Insulating Oil. Although RIP has been developed for other applications such as Insulated Busbars, the bulk usage of RIP for Bushings is reported from around 1970. Now the RIP Bushings are available up to 420 kV mainly for Air to Oil Type Application & few RIP Bushings are also reported to be available even at 800 kV Level and for Oil to Oil & Oil to SF6 Application. In India, the bulk use of RIP Bushings for Air to Oil Type Application Commenced in @ 2011. RIS (Resin Impregnated Synthetics): This is a truly Paperless Bushing (free of cellulose) and is also truly a Solid Insulation System like RIP Bushings & it has been a fairly recent development and it's reported to be undergoing field trials since 2012. First trial of RIS Bushings in India is reported to have started in 2018-19. These Bushings are readily available up to 170 kV Rating, trial usage RIS Bushings is also reported up to 245 kV class. RBP The earlier type of RBP (Resin Bonded Paper) is not discussed, as the Technology is now obsolete and the manufacturing of RBP Bushings has already stopped & hence is not discussed in the Paper. Now let us look at some of the Current Technology Trends in Bushings using OIP, RIP & RIS Technologies;

OIP BUSHINGS

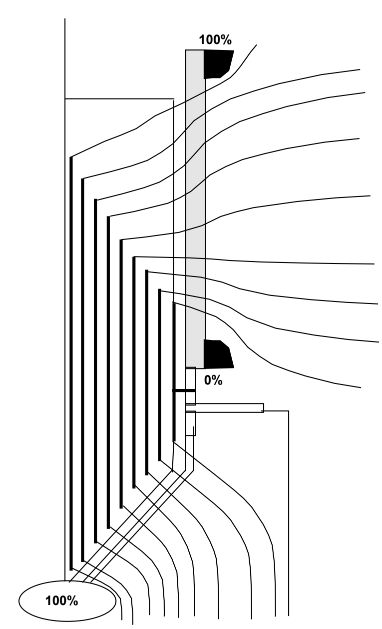
The OIP Technology is a mature technology from the Product & Process Viewpoint. However, in view of service experience, where some of the explosive failures of the OIP Bushings have caused severe damage to Transformer and surroundings, the main focus in OIP Technology has been to enhance in-service reliability of OIP Bushings. Some of the Product Features like “Shatterproof Resin Moulded Oil End Insulator” have been used by most of the Bushing Manufacturers around the world. In order to avoid shattering of Air End Insulator, Bushings with Polymeric Insulators have been designed, type tested and also are reported to be in use. However, such Bushings with Composite Insulators as Air End Insulator, are yet to become popular. Besides these product features, the focus has been to ensure and enhance reliability of Condenser Core and Drying of Paper Insulation to minimise remaining Moisture Content. So also, the focus of the manufacturers has been to ensure good quality oil (Dried and Degassed) is filled in the bushing. In order to correctly assess the Bushings’ quality, IEC Standard has undergone significant changes, such as Routine Impulse Testing of Bushings above 72.5 kV in IEC60137:2017, Routine AC HV Testing at higher voltage (i.e. 10% higher than Transformer Insulation Level). Also, some customers have made the Tan Delta limits stringent (e.g. 0.4% instead of 0.7%). The major focus has been to evolve Tests to identify defective bushing & remove it from service before it causes explosive failure & damage to Transformer. Some such offline tests have been Low Frequency Tan Delta, DGA of Oil. There are few installations in the world and in India, where On-Line Monitoring of Bushing health also has been implemented. These will be discussed later in the paper.

RIP / RIS BUSHINGS

RIP Bushing usage for Transformer Application is now nearing 50 years & the Product and Manufacturing Process has been mastered by few reputed manufacturers. The main technology trend is towards developing and establishing manufacturing capabilities for higher kV Class (>420kV) RIP Bushings for Air to Oil Type Application. Around 1970, when the RIP Bushings were manufactured there were several types of constructions i.e. Porcelain Housing + Oil Filling or Porcelain Housing + Foam etc. However nowadays the RIP Bushings available are all with Silicon Housings, unless end user specifically calls for use of Porcelain. There are two types of constructions in use at present. The first type uses Hollow Composite Insulator & Gap between RIP Condenser Core and ID of Insulator is filled with Dry Insulating Foam & in second type the Silicon Insulator is directly moulded on RIP Core. The challenge is in Direct Moulding of Silicon Sheds on Higher kV Class RIP Condenser Cores. Also, manufacturers are working on enhancing yield of first-time pass from the viewpoint of PD Performance. Another aspect on which some developmental activities are taking place is on how to reduce the moisture absorption during handling, transport & storage, although usage of Oil Filled / Dry Gas Filled tank on Oil end is more popular nowadays. For in-service condition monitoring, for RIP Bushings the main focus is on developing a low-cost on-line health monitoring device based on Capacitance Variation Method. For RIS Bushings the main efforts are in developing and productionising Air to Oil Type Bushings higher than 170 kV Class. Also, close monitoring of RIS Bushings installed about 6-7 years back, is being done in order to find out whether any unknown problems need attention. This will decide the further evolvement of RIS Bushings.

CONDENSER GRADING CONCEPTS

In order to understand the basics of Health / Condition monitoring, it is essential to look at the condenser grading concepts. The sketch shows a Typical Electrical Field (Equipotential Lines) Configuration of Oil to Air Type Bushing (OIP/RIP/RIS). As can be seen the Condenser Grading is required to control & uniformly distribute electrical field along the Air End Insulator and Oil End Insulator. The main function of Condenser Grading is also to control Radial Voltage Stress inside the Condenser Core, so that the Insulation System can be optimally and compactly designed. The condenser grading is achieved by placing Wider Aluminium Foils of different lengths at different diameter locations. Typically, in 145 kV OIP Bushing around 30 Nos. of Grading Foils are used and whereas in 145 kV RIP / RIS Bushings around 15 Nos. of Grading Foils are used. The lesser number



of Grading Foils in RIP/RIS Bushings is due to fact that Resin Impregnation requires more space between paper/ synthetic films (arranged between aluminium foils). The outermost Grading foil is connected to Test Tap & then externally connected to earth.

CAPACITANCE & TAN DELTA OF BUSHINGS

In OIP Bushings, Insulating Kraft Paper Layers are tightly wound on the Central Pipe / Central Rod and at predetermined Diameters, Condenser Grading Aluminium Foils are inserted at predetermined Locations. The Tight and Compact winding is achieved by winding the condenser core on a machine, this is necessary to minimise the oil film thickness and thus attempt to reduce adverse effects of Oil Ageing. Insulating Kraft Paper thickness used is in the range 0.075 mm to 0.125 mm & the grammage used typically in the range of 60 GSM to 80 GSM. The grade & quality of Insulating Paper used decides the dielectric constant & hence the Capacitance Value and thus the Capacitance values for same kV Class can vary between various different designs / manufacturers. Since the Condenser Cores are tightly wound, it takes few weeks for drying of the paper insulation (i.e. Removal of Moisture) under heat (@100 Deg. Cent.) & finer vacuums (finer than 0.05mBar). After the drying is completed, the Condenser is impregnated by use of well dried and degassed Mineral Insulating Oil. The dried & degassed oil at room temperature has a Tan Delta of ~ 0.001 and the total tan delta of OIP Condenser Core is mainly decided by the grade of paper used and the winding technique used. The paper to oil ratio (typically around 100:10, based on the compactness of paper winding) is a critical parameter to decide Capacitance & Tan Delta. Typical Tan Delta values of OIP Bushings is in the range of 0.003 to 0.004.

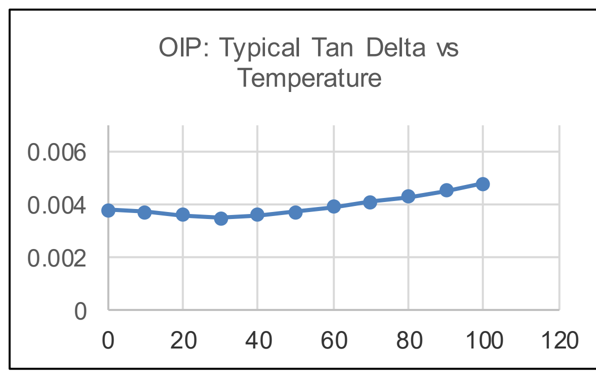
In RIP Bushings, Insulating Crepe Paper Layers are wound on Central Pipe / Central Rod and at predetermined Diameters, Condenser Grading Aluminium Foils are inserted at predetermined Locations. The optimum winding tightness is ensured to achieve impregnation by Resin Mix & also to ensure the Condenser Grading Aluminium Foils stay in position during handling and during the process of Drying and Impregnation. The typical paper to resin ratio is around 60:40. Since the crepe paper winding is not as tight as Condenser Cores for OIP, the drying (i.e. Moisture Removal) process is shorter and lesser in time than ~ 50% of Condenser Cores for OIP. The resin component itself has a relatively higher tan delta when compared with Oil. In view of higher resin content in RIP the Typical Tan Delta Values is in the range of 0.004 to 0.005 at room temperature. The only difference between RIP & RIS Bushings is, Crepe Paper is used in RIP whereas Synthetic Film is used in RIS. Thus, in case of RIS an elaborate drying of Paper similar to OIP/RIP is not required as Synthetic Film is used in RIS.

IEC-60137-2017, specifies a Limit for Tan Delta of 0.007 (Maximum) for OIP, RIP and RIS Bushings at temperatures of 10 & 40 Deg. Cent.

TAN DELTA VS TEMPERATURE

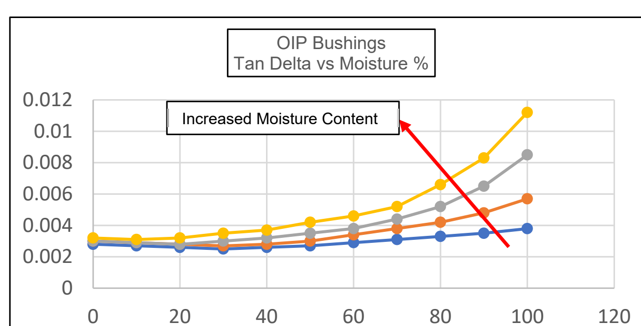
The Air to Oil Type Bushings are mounted on the Transformer Tank & Oil End Part is immersed in Hot Oil Inside the transformer and thus based on the Transformer Load conditions, oil side of bushings in service are continuously exposed to surrounding temperatures of 60 Deg. Cent. to 90 Deg. Cent. Whereas the factory tests are carried out on Bushings at Ambient Temperatures.

Thus, it is important to understand and appreciate the variation of Tan Delta with reference to Temperature of OIP, RIP and RIS Bushings & assess its performance at test bed and also during service. Based on the extensive experiments carried out on prototypes of OIP & RIP Bushings, we are sharing our findings on Tan Delta vs Temperature.



Typical Tan Delta vs Temperature Characteristics of OIP Bushings is shown in the Graph. As can be seen there is a variation in Tan Delta when the temperature is increasing. Lowest value is observed in between 20 Deg. Cent. and 50 Deg. Cent.

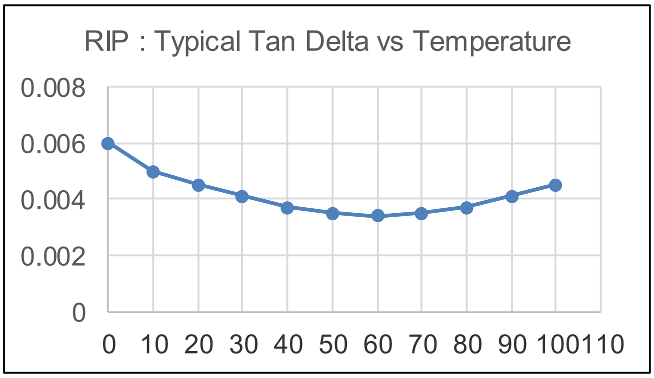
For OIP Bushings, the varying Moisture Content in Paper Insulation (Balance after the Drying Cycle), the Tan Delta is observed to be higher at Temperatures in excess of 60 Deg. Cent. This is illustrated in the representative



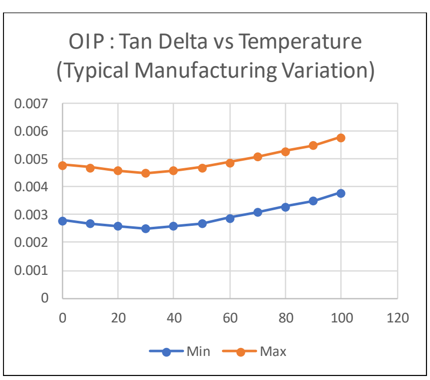
graph given below;

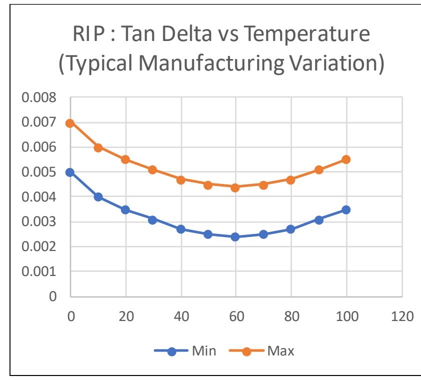
As can be seen, the higher the Moisture Content, the Tan Delta can reach very high Tan Delta values at Temperatures 60 to 90 Deg. Cent. and can result into thermal runaway and cause OIP Insulation & ultimately Bushing Failure.

In case of RIP Bushings, in view of the Inherent Resin Material Characteristics, higher Tan Delta variation (when compared with OIP) is observed w.r.t. Temperature, as shown below;



As can be seen from the graph, the RIP Bushing has lowest Tan Delta value at Temperature of @ 60 Deg. Cent. The Tan Delta keeps increasing as Temperature goes below 60 Deg. Cent. A similar Tan Delta behaviour is reported in RIS Bushings also with slightly lower values than in RIP Bushings. Based on statistical analysis of data on variations in manufacturing processes of OIP & RIP Bushings, below mentioned Minimum & Maximum limits have been arrived at;





From the above description, it is essential that the users seek the data of Tan Delta vs Temperature from the Bushing Manufacturer and use it as a guidance during health assessment based on site measurements. Also, it can be concluded that for OIP Bushings, a Stringent limit on Tan Delta such as 0.004 can be adopted, however for RIP / RIS Bushings being Solid & has practically non ageing insulation, Tan Delta limit does not need to be stringent and limit of 0.007 can be adopted for RIP & RIS. So also, the variation in Tan Delta with Temperature has to be given consideration while evaluating measurements carried out at Bushing Factory, Transformer Factory & Site Measurements.

CAPACITANCE VS TEMPERATURE

Capacitance has a linear variation with temperature & is mainly decided by variation of Composite Dielectric Constant variation with Temperature. The typical variations of Capacitance of OIP, RIP & RIS are 0.025% per Deg. Cent. for OIP; 0.08% per Deg. Cent. for RIP & 0.03% per Deg. Cent for RIS. If we consider, a Bushing has a Capacitance Value of 350pF at 20 Deg. Cent., and if we estimate Capacitance at 50 Deg. Cent. based on above Temperature Coefficients; in case of OIP Bushings the Capacitance will be 352.6pF, for RIP Bushings it will be 358. 4pF, for RIS Bushings it will be 353.2pF. Another consideration is, if we have 50 nos. of Condenser Foils for 245 kV Bushing (this means we have 50 capacitors in series) & in case there is a puncture of one foil (i.e. short of one capacitor), the change in capacitance expected is approx. 350pF x 1/50 = 7pF. Thus, during site measurements, we need to take into account Temperature of Insulation at the time of Capacitance measurement & change in capacitance caused by puncture of one foil segment and then decide health and status of Bushing. An easy method to decide whether puncture or temperature effect caused the variation is to compare similar bushings in similar conditions, typically the 3 phases on a same transformer: same increase on 3 phases is most probably due to temperature or environment; variation on one phase is probably due to a puncture.

INSULATION DEGRADATION IN SERVICE

As it has been reported in several technical papers and confirmed by our experience, for OIP Bushings the Insulation Degradation is mainly caused by decrease in Insulation Resistivity caused by Moisture Ingress (caused by leakages thru sealing) & Contamination external to Condenser Core (due to degradation of Oil). This causes increased resistive loss and thus increase in Tan Delta value. This results in increased dielectric heating thus further increase in Tan Delta & eventually breakdown due to thermal runaway. PD (Partial Discharge) activities start in small segments but with periodic larger size discharges & these keep on increasing with time. As the discharges increase, puncture holes of smaller size containing conducting path are created & these result in increase of Capacitance Value. Thus, in OIP Bushings, all three parameters viz. "Capacitance", "Tan Delta" & "DGA" are important to be monitored. Whereas in case of RIP/ RIS Bushings, the Insulation degradation takes place due to PD activity taking place over a smaller area in RIP / RIS Condenser Core. As PD Activities increase, tree like structure gets converted into small hole and as the discharges further increase, the hole size increases; ultimately resulting in creating a shorting / conducting path between two or more condenser foils. Thus, there is an increase in Capacitance. The Condenser Core does not have oil and hence does not interact with Oil like OIP Bushings and thus no adverse effect on Tan Delta in case of RIP/ RIS Bushings. In case of RIP / RIS Bushings, during service Tan Delta remains steady and show insignificant changes. Thus, for RIP/RIS, Capacitance monitoring is an effective method.

HEALTH MONITORING IN SERVICE

In order to prevent Explosive failures of Bushings (causing severe damage to Transformers and surroundings), health monitoring of Bushings has gained significant importance. As reported in CIGRE Report 755 published in Feb-2019, about 83% of users follow the Off-Line Diagnostic methods. About 96% of these users still follow Capacitance & Tan Delta measurement. The off-line diagnostic measurement periodicity followed is between 2 & 4 years. Few of critical aspects of measuring Capacitance & Tan Delta at Factory (Bushing & Transformer) vs Site Measurements are listed below;

- Factory measurements are more accurate due to measurements in interference free environment in shielded laboratory & use of loss free standard capacitor.
- Site measurements are mainly dependent on characteristics of standard capacitor in the portable bridge & the measurement method used.
- Adverse Effects of Surface Contaminations on Tan Delta measured at site. This effect is more pronounced for bushings of lower kV Classes (36 kV to 72 kV) and having been exposed to environmental condition for longer time.
- Effect of Temperature at the time of measurement at site. External ambient temperature may be lower, however the time gap between shutdown and measurement will decide the actual temperature of condenser body & hence will affect results measured. CIGRE Report 755 elaborates the method of assessing Actual Bushing Temperature.

Tan Delta Limits for New Bushings & for Bushings at Pre-commissioning and in Service

New Bushings: IEC 60137 limits of Tan Delta for OIP, RIP & RIS Bushings of 0.007 (Maximum) between Temperatures of 10 & 40 Deg. Cent. is adopted by most of the utilities in the world. This is due to the fact that Tan Delta does not reflect healthiness of RIP & RIS Bushings. Pre-Commissioning: In RIP Bushings, Condenser Core itself forms the Oil End Portion (similar in RIS Bushings). In view of Moisture Absorption by RIP Condenser Core (i.e. by exposure of Oil End Part to ambient), there is an adverse effect on increase of Tan Delta at pre-commissioning stage. Hence RIP Bushings are usually supplied fitted with Oil / Gas Filled Metallic Containers fitted at Mounting Flange Level, to prevent the moisture absorption due to long exposures to ambient. In case of OIP Bushings, there is a possibility of De-Impregnation (drying of OIP condenser core) if not stored as per manufacturer's recommendation. Hence, some users follow the practice of vertical storage of OIP Bushings to prevent the de-impregnation. To account for the difference between factory and site measurements, it is recommended to allow variation of +/-0.001 between Factory and Pre-commissioning results at site and comparable temperatures. This is aimed at taking into account effects mentioned in above paragraphs. In Service: Tan Delta as a monitoring parameter is most important for OIP Bushings and it is not important monitoring parameter for RIP/RIS Bushings, as Tan Delta remains steady during service. There can be two methods of monitoring Tan Delta in service, first is the absolute limiting value and second is the rate of increase of Tan Delta. Based on study of Technical Literatures and our experience, limit of absolute Tan Delta as 0.008 (and / or Double of Pre-Commissioning Value) is recommended for OIP Bushings. Rate of increase of Tan Delta <0.0002 per year can be treated as healthy & however sudden increase of Tan Delta within two readings from normal increase of 0.0002 to 0.001 should be treated as a sign of concern & as a "Warning" signal. Tan Delta measurements at Different Frequencies (15 Hz to 400 Hz at 2 kV or 4 kV): On account of difficulties in correct assessment of Tan Delta in service based on 50 Hz measurement for OIP Bushings, through research by experts around the world have evolved Tan Delta measurements at different frequencies. The Low Frequency Tan Delta measurements give a definitive indication of Moisture Presence for OIP Bushings. About 13% of the users are reported to have followed these measurements as a tool to confirm degradation of OIP Insulation. In recent CIGRE-Session 2018, POWERGRID-India presented case studies on these measurements. It is established that lower frequency measurements, show moisture content distinctively and thus more of a confirmation test. CIGRE document gives guidelines on new and aged bushings.

DGA of Oil Sample from OIP Bushings: In order to supplement evaluation based on Tan Delta, DGA is more of a conclusive measurement. Broad Guidelines are available in IEC-61464 and limits on DGA are given in these standards. Oil Sampling from Bushings needs extreme precautions to be exercised as recommended by manufacturers, to prevent moisture and Gas ingress during sampling. Limiting quantity of Oil Sampled (less than 25mL) is best suited for multiple analysis during entire service without refilling of oil. Trend of Increase in gases is the best method to follow rather than limits on gases. Refer limits given in IEC 60599.

Online Capacitance Monitoring: This is practiced by few users around the world. The main principle is to assess variation in Capacitance of a set of three bushings. There are some case studies where users have reported success. The most efficient method to conclude if changes are due to environment, to grid variations or to bushing failure is to couple a HV-voltage divider with the bushing to be monitored and compare both values on real-time. However, these are only used at kV Classes > 245 kV, in view of prohibitive costs of such devices.

SUMMARY

A larger population of OIP Bushings is in Service, & Monitoring of the Healthiness of OIP Bushings is important to prevent Explosive Failures. Methods adopted are Limiting Values of Tan Delta in Service or Detecting Rate of Change of Tan Delta. Capacitance Change to provide clue on Puncture of Foil Segments. DGA is a must for 245 kV & 420 kV Bushings , Oil Volume Sampling to be limited to 25 mL. PD Evaluation in a Laboratory can be treated as a confirmation Test. RIP Bushings are popular since 2011 in India, due to distinct advantages. Fool-proof Storage, to prevent Moisture Absorption & degradation of Tan Delta before commissioning. Limiting Values of Tan Delta for RIP / RIS can be higher than OIP. Recommended to follow IEC Limits of 0.7% (Take into account Temperature vs Tan Delta behaviour). Lower Tan Delta Limit at ambient temperature does not necessarily mean better quality product for RIP / RIS Bushings (provides no information regarding tan Delta at operating temperature). Tan Delta not expected to reveal health of RIP/RIS in service, Hence Capacitance Change to be adopted as a health monitoring tool. For RIS Bushings, more Service Experience needs to be gained to define the health monitoring strategy, however till such time Capacitance Based Monitoring like RIP Bushings can be followed.

BIBLIOGRAPHY

1. CIGRE : Doc No. 755 (2019) by Working Group A2.43 – Transformer Bushings Reliability.
2. CIGRE : Doc No. 445 (2011) ,642 (2015), 761 (2019) by Working Group A2.37 – Transformer Maintenance, Transformer Reliability Survey & Condition Assessment. IEEE C57.143 -2012 Guide for Application for Monitoring Equipment – Transformers & Components
3. INMR-Dec 2015 & Doble-2014 : Article by HSP Experts on "Evaluating Reliability of Bushings & Related Case Histories".
4. Evaluation and Identification of Typical Defects and Failure Modes of 110-750kV Bushings by Victor Sokolov and Boris Vanin, ZTZ-Service Co.
5. Advanced Diagnostic Tests on High Voltage Bushings by Dr. Michael Kruger, Omicron.
6. CIGRE Session Technical Paper "A2-203" by ABB & Swedish National Grid. & A2-208 by POWERGRID India.

Power Quality Analysis in Power Distribution Network

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ABSTRACT

Untill now Distribution utilities are only concentrating on reliability and availability of power. Present performance standards are also focusing on these two parameters. There is lot of improvement in infrastructure of distribution utilities across India which has been resulted in improvement in reliability and availability of power since last one decade. However there is almost negligible work done in the area of power quality until now in distribution sector. This paper discusses power quality parameters manifested in standards and measurement results carried out at 02 no site in BSES Yamuna Power Limited.

1. INTRODUCTION

There is no clear definition available for power quality. This term is used differently by different domain expert. As per utility, power quality is to provide reliable and continuous power supply. Whereas as per customer, power quality means power supply which enable smooth operation (Uninterrupted) of their equipments.

Electric Power consist of three parts Voltage, Current and Phase Angle. Quantity that can be thought in the control of utility is the voltage (Supply voltage at customer terminals). Current and phase angle depends upon type of load used by customer and characteristic of this supply voltage provided by utility.

Hence from a perspective of utility power quality can be described as specified characteristic of supply voltage in term of magnitude as well as waveform.

Both IS 17036: 2018 and EN50160 defined characteristic of voltage quality as follow:

i. Frequency
ii. Magnitude
iii. Waveform and
iv. Symmetry of line voltages

Power quality measurement has been taken at 02 no's sites in BSES Yamuna Power Limited for 03 months. Results of same have been analysed with respect to different standards. These sites are as follow:

i. Site A: 11 KV Outgoing feeder at Vivek Vihar 33/11 KV grid Substation of BYPL
ii. Site B: 33 KV Outgoing feeders at Shastri park East 66/33 KV Grid Substation of BYPL

2. POWER QUALITY PARAMETERS

Power quality/ Voltage quality generally manifested in term of following parameters:

i. Variation in Supply Voltage Frequency
ii. Variation in Supply Voltage
iii. Rapid Voltage Changes
iv. Flicker Severity
v. Supply Voltage Unbalance
vi. Long Interruptions
vii. Short Interruptions
viii. Voltage Sags/ Voltage Dips
ix. Voltage Swells
x. Transients
xi. Harmonic Voltages

2.1 Variation in Supply Voltage

This is Increase or decrease of root mean square (r.m.s.) voltage normally due to load variations. This parameter has been part of performance standards of a utility since many years. However voltage quality standards (IS 17036) have made measurement analysis of this parameter standardize as per IEC 61000-4-30. Parameter taken for measurement is Mean r.m.s. valu of the supply voltage over 10 min. Results of measurement done at BYPL is summarized in Table 1.

2.2 Variation in Frequency of Supply Voltage

This is repetition rate of the fundamental wave of the supply voltage measured over a given interval of time. Parameter taken for measurement is mean value of the fundamental frequency measured over 10 s. All the 10 s values measured over a week shall be taken for threshold given in standards. These threshold and value measured at BYPL has been given in Table 1.

2.3 Supply Voltage Unbalance

Condition in a polyphase system in which the root mean square (r.m.s.) values of the line-to-line voltages (fundamental component), or the phase angles between consecutive line voltages, are not all equal. This is measured in terms of percentage of rms of positive phase sequence to –ve phase sequence of line voltages follow:

$$\% \text{ of Unbalance} = \frac{\text{rms of + ve Sequence}}{\text{rms of - ve Sequence}} \% \; 100 \; \%$$

Following are the salient reasons and effect of voltage unbalance in a distribution system.

Reasons	Effects
• Unbalanced Generations • Unbalanced load • Unequal source impedances. • Single phase/ 2 phase faults. • Rapid voltage chnages etc.	• Overheating of electric motors. • Operation of power electronic equipments.

It is also observed that rapid voltage change (RVC), sag and Interruptions in power supply gives rise to voltage unbalance condition. Please refer Fig. 1.

Measurement done at BYPL has been provided in Table 1.

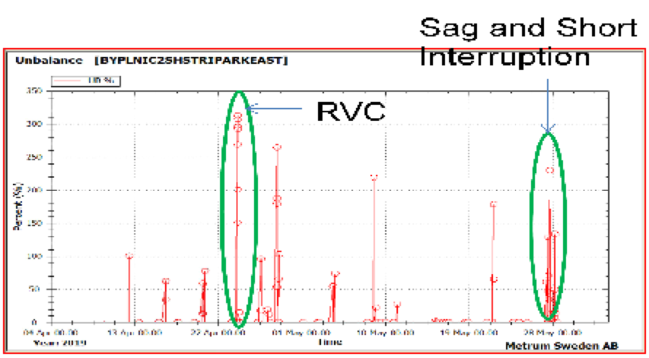


Fig. 1

2.4 Flickers in Supply Voltage

This is Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time. This is measured in long term flickers (Plt) and short term flickers (Psti) as defined in IEC 61000-4-30. A flicker does not have any damaging effect on power system or equipments. Their only effect is irritation to the consumer. Some of its reason and its effect have been summarized below.

Reasons	Effects
• Sudden load changes. • Rapid voltage changes. • Faults, interruptions etc.	• Irritation to consumer due to constant change of brightness of light bulb.

It is also observed that rapid voltage changes also gives rise in flickers values especially in Psti. Please refer Fig. 2.

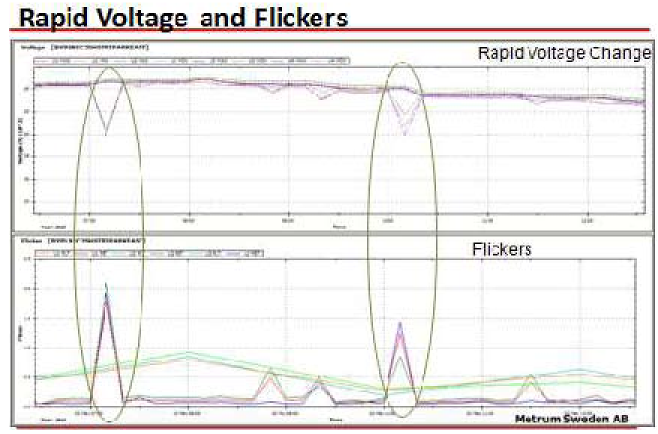


Fig. 2

2.5 Harmonic Voltage at Point of Common Coupling

Every non sinusoidal but periodic signal can be divided into several sinusoidal signals having frequency in the multiple integers of original signal's frequency. These components are called harmonics.

Generation of harmonics is mainly due to presence of non linear loads in the power system. A non linear load draws a non sinusoidal current. This current will produce a non sinusoidal voltage in the line impedances of distribution system. Hence the terminal voltage at the point of common coupling will also be non sinusoidal. If other customer having linear loads will be connected to this terminal then it will receive a distorted voltage supply.

Effect of current harmonics over voltage of point of common coupling will depend upon amount of harmonic components in current and value of line impedances upstream to this point. More is the line impedances more is the distortion effect on terminal voltage due to distorted current.

Measurements done at BYPL sites have been given in Table 1.

Table 1

SL	Parameter	Parameters Standards			Observations	
		IS 17036	En50160	EIFS	Site A	Site B
1	Frequency Variation	99.5 % of 01 Week	fn ± 1 % for 99.5% of 01 year period +4%/-6% for 100% of the time	Not specified	+0.16% to -0.25% +0.33% to -1.73%	+0.16% to - 0.25%

SL	Parameter	Parameters Standards					Observations	
		IS 17036		En50160		EIFS	Site A	Site B
2	Voltage variation	Period	LV V<	MV	HV	Un ± 10 % for 100% of time	MV	MV
		95% of 01 week	Un ± 10 %	NA	NA		NA	NA
		99.5 % of 01 week	NA	Un ± 10 %	NA		+3.8 % to -6.5 %	+5.06 % to -3.69 %
		100% of the time	Un +10% to -15 %	Un ± 15 %	Un ± 10 %		+5.1 % to -9.2 %	+6.49% to -4.53%
3	Supply Voltage Unbalance	<2% for 95% of 01 week				<2% for 100% of time	0.57%	0.62%
4	Flicker Severity	Plt<1% for 95% of 01 week				Plt<1% for 95% of 01 week	0.6%	0.8%
5	Supply Voltage Harmonics (THD)	≤ 8 % for 100% of time				≤ 8 % for 100% of time	0.6%	1.52%
6	Supply Voltage Harmonics (Individual)	≤ As per Table for 95% of 01 week				≤ As per fig 3 for 100% of all time	In Limits	In Limits

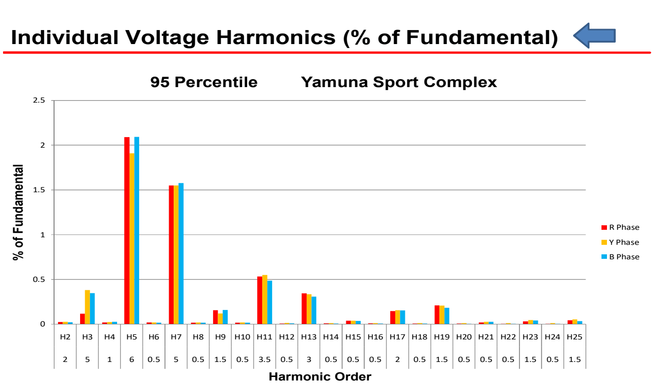


Fig. 3

3. VOLTAGE EVENTS

3.1 Voltage Sag (Dip)

Temporary (10 ms to 1 min) reduction of the root mean square (r.m.s.) voltage at a point in the electrical supply system below 90% of nominal value. Voltage Sag measured in Magnitude of voltage and time. Voltage sags recorded at site A and Site b of BYPL has been provided in Fig. 4 and Fig. 5 respectively.

3.2 Voltage Swell (Temporary Power Frequency Over Voltage)

Temporary (10 ms to 1 min) increase of the root mean square (r.m.s.), voltage at a point in the electricity supply system above 110% of nominal value. Voltage Sag measured in Magnitude of voltage and time.

3.3 Transients

Short duration oscillatory or non-oscillatory over voltage usually highly damped and with a duration of a few milliseconds or less.

3.4 Rapid Voltage Change (RVC)

RVC is a single rapid variation of the rms value of a voltage between two consecutive levels which are sustained for definite but un-specified durations.

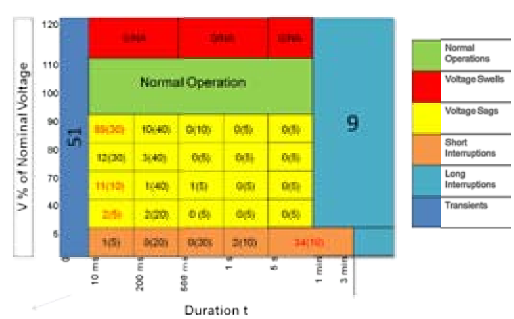


Fig. 4

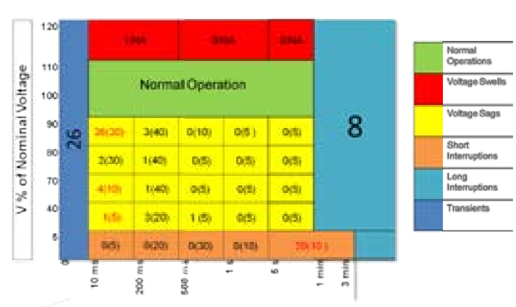
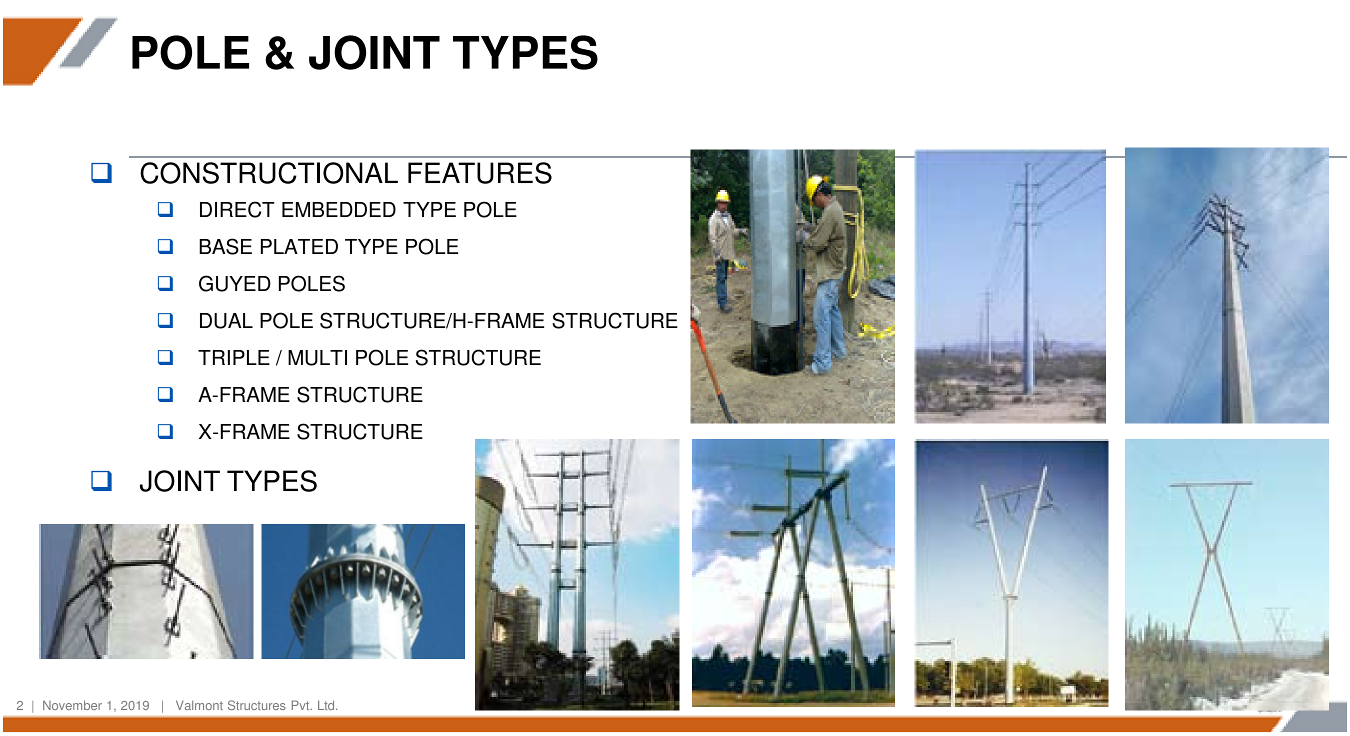


Fig. 5

Innovative Solutions Using Steel Tapered Poles for Utility

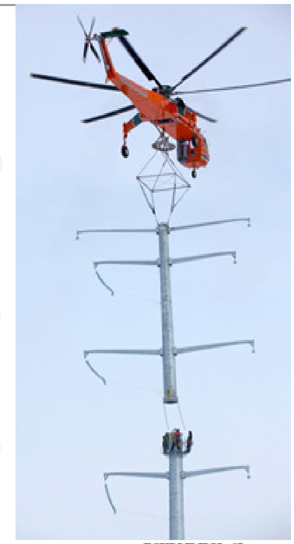
Dayanand Swamy Kuna

Valmont India



STEEL POLE ASSEMBLY & INSTALLATION

- HORIZONTAL / GROUND ASSEMBLY
- VERTICAL / SECTION BY SECTION METHOD
- VERTICAL BY HELICOPTER METHOD
- POLE INSTALLATION BY HYDRULIC JACKS / HOIST



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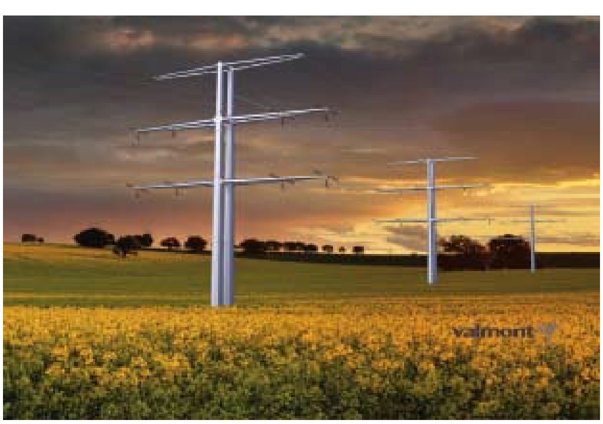

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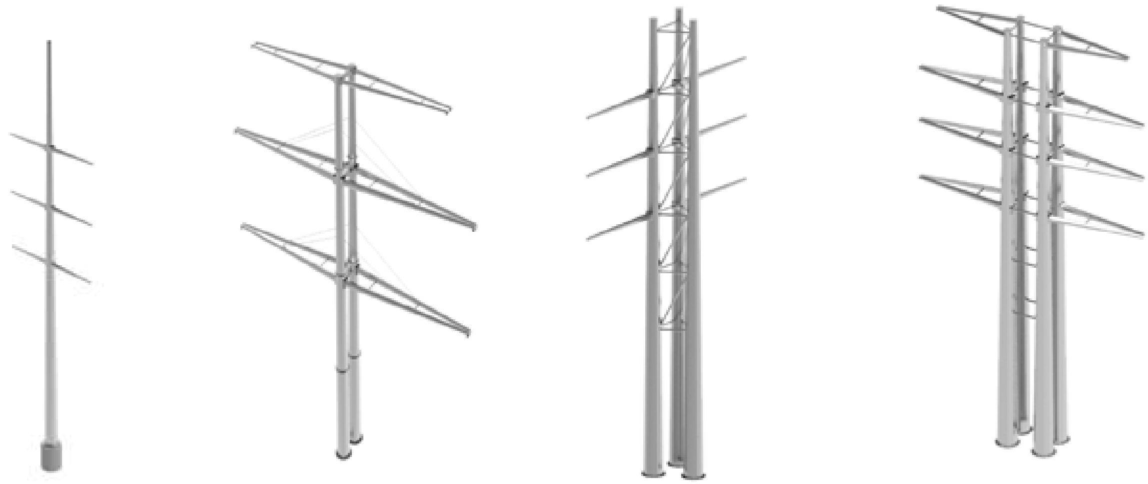
MULTI POLE STRUCTURES

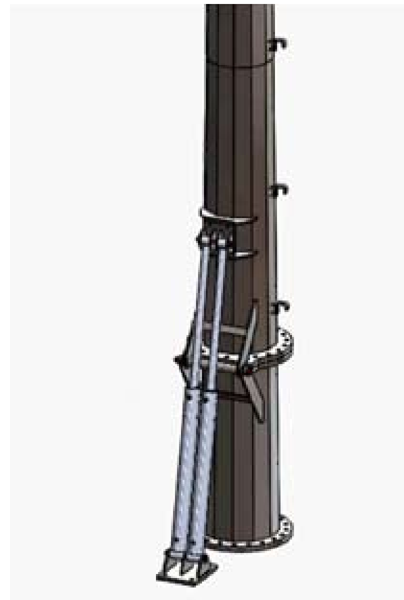


Monopole Dual Pole Triple Pole Four Pole

132 kV S/C, MSETCL

132 kV D/C, MSETCL

132 kV D/C, LILO Pole, MSETCL



Life is a Combination of Success and Failure Both are Needed

Development of 1 MWh Battery Based Energy Storage System for Renewable Integration

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ABSTRACT

Battery based Energy Storage Systems (BESS) are becoming more popular in view of advancement in battery technologies together with reduction in price and penetration of renewable energy into the grid. BHEL has developed 1 MWh BESS for renewable integration for ramp rate control and capacity firming. As this pilot project also aims at evaluating very promising batteries, 1 MWh BESS has been realized using 500 kWh Li Ion battery, 300 kWh advanced Lead Acid battery and 200 kWh Flow battery. The developed BESS has been integrated with 500 kWp SPV plant and have been successfully operating in ramp rate control and capacity firming applications. The performance of the three batteries are also evaluated. System level design, development of Energy Management System (EMS), IGBT based Power Conditioning System (PCS) and communication between various sub-systems were developed by BHEL with in-house efforts.

1. INTRODUCTION

India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source with environmental friendly. It also has the advantage of permitting the decentralized distribution of energy thereby empowering people at the grassroots level. However, due to the intermittent nature of the solar power generation, the increase in the share of solar generation in the total power generation will pose challenges in the grid stability and requirement of higher peak generation capacity. This poses a challenge for the penetration of renewable energy resources into the grid and thus puts limitation on harnessing the solar energy. To mitigate this problem, grid level storage technologies are being evolved globally for renewable integration. An appropriate Energy Storage System in parallel with SPV power plant can smoothen its power output over a period of time and thus avoids the fluctuating power output.

In view of the advancement in various battery technologies and decreasing trend of battery prices, BESS is becoming popular for both power & energy applications, in particular renewable integration for output smoothening. However, the non-availability of indigenously developed grid level Energy Storage System (ESS) and its higher cost are challenges for country like India to leverage the full benefits of ESS for penetration of solar energy in India.

BHEL is always in the forefront in meeting the India's energy requirements and to continue its legacy in this field, it has indigenously developed 1 MWh grid connected Battery based Energy Storage System (BESS) for renewable integration. This is the first of its kind in India. The developed system was commissioned and integrated with 500 kWp SPV plant at Corp R&D for ramp rate control / output smoothening (mitigation of sudden change of solar power export to the grid due to changes in solar irradiation). As each battery technology has its own merits and demerits, the performance of three different batteries were also evaluated and thus 1 MWh was realized using 500 kWh Li Ion battery, 300 kWh advanced Lead Acid battery and 200 kWh Flow battery. Besides the renewable integration, the ESS finds its applications in distributed generation, peak load shaving, load levelling, frequency regulation, spinning reserve and power quality improvement.

2. PRINCIPAL OPERATION OF BESS

The applications of energy storage systems have broadly classified into two categories. (1) Power applications (2) Energy applications. The list of applications is given in Table 1.

Table 1

Energy Application	Power Application	
(hours)	(seconds)	(minutes)
• Peak shaving • Output smoothening of renewable energy resources • Energy trading/arbitrage • Source leveling • Grid reliability Islanded operation Line upgrade deferral	• Voltage support • Frequency Regulation • Flicker compensation • Transient • LVRT support	• Spinning reserve • Unbalanced load Compensation • Uninterruptible Power supply • Black start

The SLD of a typical grid level BESS is as shown in the Fig. 1. The major sub-systems are (a) Battery & BMS (b) Power Conditioning System (PCS) (c) Energy Management System (EMS) (d) Switch gear.

The grid level BESS will be designed to export / import of active power to the grid as per grid requirement. EMS executes the ESS application such as frequency regulation of the grid, renewable integration for ramp rate control, time shifting, peak load shaving…etc and determines the amount of active power to be exchanged (export / import) with the grid and thus generates the active power reference to the PCS.

The PCS is a Voltage Source Converter (VSC) which is a bi-directional converter which will be controlled to synchronize with the grid and exchange power with the grid. If PCS injects power into the grid, it takes dc power from the battery and converts into ac power in sync with grid; if PCS absorbs power from the grid, it converts ac power into dc power and charge the battery accordingly. The PCS will be connected to the grid through a suitable transformer, if the PCS voltage is different from grid voltage.

Battery is the storage element of ESS. It can be lead acid, Nickel cadmium, Lithium Ion, flow battery, Sodium sulphur etc. Battery will be charged and discharged depending on the mode of operation of ESS.

BMS will ensure extended life of battery and safety of operation. It measures voltage, temperature, current and State of Charge (SOC) of the battery and communicates the same to PCS and EMS for control and protection purpose.

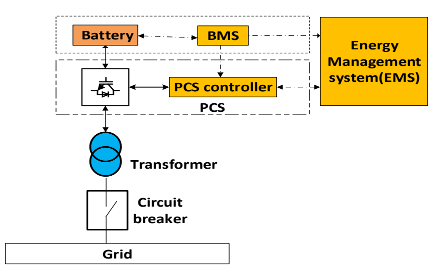


Fig. 1 : Single Line diagram of BESS

3. DESCRIPTION OF 1 MWH BESS

1 MWh containerized BESS was developed for ramp rate control / output smoothening of the existing SPV plant. The project was demonstrated for 500 kWp grid connected SPV power plant at Corp R&D, BHEL Hyderabad for both ramp rate and capacity firming control. The SLD of the BESS along with existing SPV plant is as shown in Fig. 2. The 1 MWh ESS is comprises of 500 kWh Lithium Ion battery, 300 kWh Advanced Lead acid battery and 200 kWh Flow battery. 500 kWh Li Ion battery, 300 kWh Advanced Lead acid battery and 200 kWh Flow battery along with its associated Battery Management System (BMS) and Power Conditioning System (PCS) are housed in 40 Ft, 30 Ft and 20 Ft containers respectively. A view of the containerized 1 MWh BESS is as shown in Fig 3. The existing SPV power plant is connected to 6.6 kV bus of R&D power system to exchange power with the grid. The IGBT based Power Conditioning Unit (PCU) of the SPV plant is connected to grid through a 320 V / 6.6 kV step-up transformer.

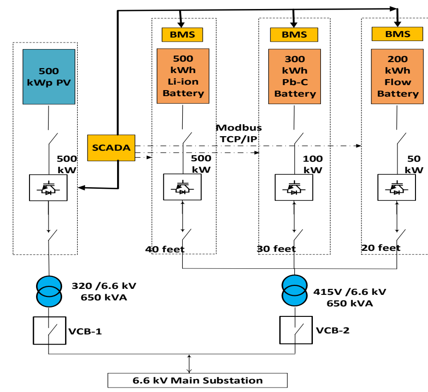


Fig. 2 : SLD of the 1 MWh ESS along with existing 500 kWp SPV power plant

Fig. 3 : A view of the containerized 1 MWh BESS

The developed ESS system is connected in parallel to the existing SPV power plant at 6.6 kV level to smoothen the power output from solar power plant such that the ramp rate of power change at 6.6 kV bus from both SPV plant and ESS system together is limited to 10% of 500 kW and thus power fluctuations at the point of common coupling are mitigated. Each battery is connected to the grid through its independent IGBT based PCS through suitable switch gear to exchange power independently of other two batteries. The Energy Management System (EMS) implements the ramp rate control / capacity firming control algorithm and accordingly determines the amount of power export / import from each battery. Based on the control logic implemented in the EMS, it generates the command to the PCS either to absorb or supply power from the grid. If the generated solar power is more than the pre-determined power output, PCS will receive command to absorb the power i.e. charge the battery and vice versa.

As the design of the ESS is modular, it can be scaled-up to the any level depending on the size of the SPV plant. Thus, ESS acts like a catalyst in increase of share of renewables to 50 % of total generation as planned and enables our country to harvest solar energy to the maximum.

The developed ESS meets the compliance requirements such as anti-islanding protections, EMI/EMC, grid harmonics …etc. as per UL1973 standard.

The user can also configure the ESS system to operate in reactive power control / pf control mode through HMI.

The ESS can also be configured for other grid applications such as peak load shaving, load leveling, frequency regulation, power quality improvement and spinning reserve.

3.1 Energy Management System (EMS)

EMS is a centralized controller which determines the power reference for the PCS for export / import of power from battery by implementing either ramp rate control / capacity firming. EMS applications and Human Machine Interface (HMI) are realized on Metso DNA control hardware. The user can choose the application (either ramp rate control or capacity firming) through HMI and accordingly EMS invokes that application and implements the same

The following control Functions are implemented on EMS.

(a) Real time monitoring of Solar Power generation by communicating with Solar PCU through Modbus

(b) Determine the state of battery in terms of SOC and healthiness by communicating with BMS of the battery through Modbus

(c) Power reference generation to the PCS and communicates the same to PCS through Modbus

(d) Control and monitoring of Balance of Plant (BoP) like VCB, transformer protections, Firing Fighting system and thermal management…. etc.

Besides these functions, EMS can also be configured to interact with grid side controller directly on real time basis for control of power export/ import.

3.2 Power Conditioning System (PCS)

PCS is an IGBT based Voltage Source Converter which responsible for exchange of power between BESS and the grid. In the case of export of power as determined by the EMS, it draws dc power from battery and pumps AC power to grid. In the case of import of power, it draws AC power from the grid and converts into DC power and charge the battery. Thus, PCS is responsible for grid synchronization, power conversion and charging/discharging of the battery. It also receives the power reference from EMS through Modbus communication. PCS is controlled to exchange active power with unity power pf at point of common coupling.

500 kWh Li ion battery, 300 kWh ADLA battery and 200 kWh Flow battery are connected to the grid through 500 kW PCS, 100 kW PCS and 50 kW PCS respectively. The control functions of PCS have been realized using the state of the art DSP and FPGA based control hardware.

A view of in-house developed 500 kW PCS is as shown in Fig. 4.

Fig. 4 : A view of In-house developed 500 kW PCS

3.3 Battery and BMS

Details of 500 kWh Li Ion battery

Cell chemistry	Lithium iron phosphate
Nominal Cell voltage & AH	3.2 v,80 AH (Max V 3.6v, Min V 2.7v)
Module configuration, voltage & AH	6S2P, 19.2 v,160AH
No. of Modules connected in series in a cluster	42
Cluster energy, nominal voltage and current	129 KWh, 806.4v, 160AH
No of clusters connected in parallel	4
Total Energy	516 KWh

Details of 300 kWh ADLA battery

Cell chemistry	Lead Carbon
Nominal Cell voltage & AH	2.0 v, 810 AH (Max V 2.4v, Min v 1.75 Vv)
No. of Modules connected in series in a cluster	36
Cluster energy, nominal voltage and current	584 KWh,720v, 810AH
No of clusters connected in parallel	1
Total Energy	584 KWh

Details of 200 kWh Flow battery

Cell chemistry	Vanadium + sulphuric acid
Nominal Cell voltage & AH	1.35 v,1300 AH (Max V 1.65v, Min V 1.00v)
No. of Cells connected in series in a stack	39
Cluster energy, nominal voltage and current	52.5 KWh,52.5V, 1300AH
No of clusters connected in parallel	4
Total Energy	273 Kwh

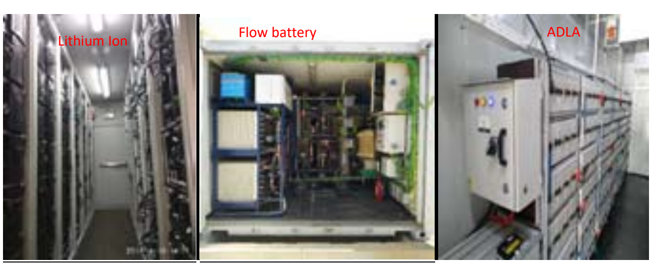


Fig. 5 : Internal View of Li-Battery, Flow Battery and ADLA BESS

4. PERFORMANCE RESULTS

The developed 1MWh BESS has been integrated with 500 KWp Solar PV Plant and its performance is evaluated for response of three types of batteries, ramp rate control and capacity firming for existing 500 kWp SPV plant.

(a) The response of Li Ion battery + PCS for change in input command to PCS from export of power to import of power from grid, is given in the Fig. 6. It shows the change in direction of ac and dc currents. The response of power reversal (i.e. Response of (battery + PCS)) is less than 20 msec.

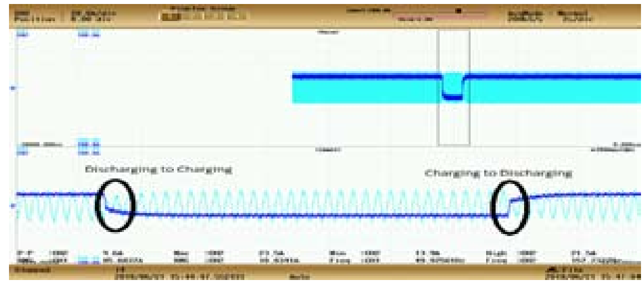


Fig. 6 : Performance of BESS in Capacity Firming operating mode

(b) BESS is configured for capacity firming applications with a pre-determined committed power of 250 kW from morning 7 am to 6 pm at 6.6 kV outgoing feeder of Corp R&D. Fig. 7 shows the constant power of 250 kW at outgoing 6.6 kV feeder irrespective of change in solar irradiation / clouds movement.

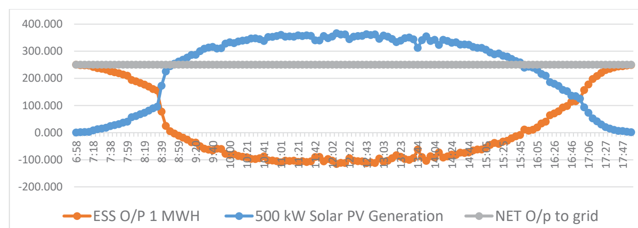


Fig. 7 : Performance of BESS in Capacity Firming operating mode

(c) BESS is configured for ramp rate control with a pre-determined ramp rate limit of 10% per min of SPV capacity i.e. ± 50 kW per min change at 6.6 kV outgoing feeder of Corp R&D. Fig. 8 shows the mitigation / limitation of power export rate within the desired limits at 6.6 kV feeder irrespective of change in solar irradiation / clouds movement.

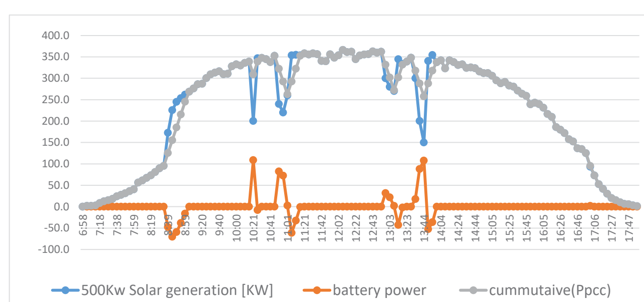


Fig. 8 : Performance of BESS in ramp rate control operating mode

(d) Fig. 9 shows the zoomed portion of the ramp rate control performance. As it can be observed, within a short time step, SPV generation falls from 190 KW to 50 KW. During this disturbance PCC Power is reduced slowly with ramp rate control by injecting power from Battery energy storage system. Similarly, during rise of solar PV power generation from 50 KW to 190 KW PCC, the net power change at 6.6 kV feeder is limited to desired level by ramp rate control algorithm by absorbing Power in the BESS.

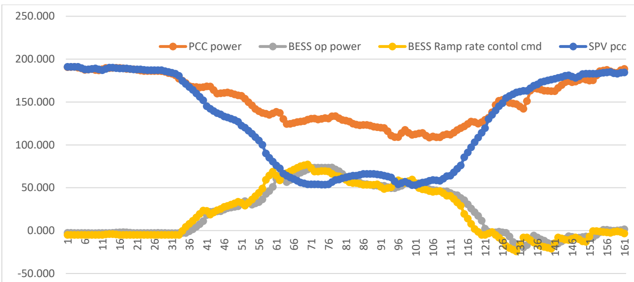


Fig. 9 : BESS performance for Ramp Rate Control with time step resolution of 1sec during cloud movement

5. BENEFITS OF THE SOLUTION IMPLEMENTED

The developed ESS technology can also be used for the following applications

(a) Distributed power generation for powering remote areas where grid is not available.

(b) Peak load shaving and load levelling and thus investments in the transmission sector can be deferred.

(c) Power quality improvements like improvement of voltage profile and frequency regulation

(d) Spinning reserve

6. CONCLUSION

The Indigenously developed 1MWh system has been tested for Capacity Firming and Ramp Rate control application. The performance of the system was found to be within the desired limits for fast variations in Solar PV generation as desired and successfully operating for the last 6 months. The total system design, development of PCS, EMS and communications with various sub-systems were developed indigenously within BHEL. Using In-house developed EMS, all three types of batteries were centrally monitored and controlled to achieve efficient and safe utilization of storage system. Further BHEL is working on peak load shaving, time shifting of energy consumption and micro grid applications.

REFERENCES

1. S. Eswara Rao, Dr.Bishnu Prasad Muni, Prashant Jain, CPV Krishna Reddy, Dr. PV Balasubramanyam "Development of 2.5MVAR STATCOM for Arc Furnace Applications" IECON 2012-38th Annual Conference on IEEE Industrial Electronics Society

2. M.J.E. Alam, K.M. Muttaqi, and D. Sutanto, "A novel approach for ramp-rate control of solar pv using energy storage to mitigate output fluctuations caused by cloud passing," IEEE Transactions on Energy Conversion, vol. 29, no. 2, pp. 507–518, June 2014.

3. M.J.E. Alam, K.M. Muttaqi, and D. Sutanto, "Mitigation of rooftop solar pv impacts and evening peak support by managing available capacity of distributed energy storage systems," IEEE Transactions on Power Systems, vol. 28, no. 4, pp. 3874–3884, Nov 2013.

International Tutorials and Colloquium on Rotating Electrical Machines in Conjunction with Meeting of CIGRE Study Committee SC-A1 – A Brief Report

21st - 28th September 2019, New Delhi, India

Mr. I.S. Jha, Hon'ble Member CERC; Mr. Gurdeep Singh, CMD, NTPC and Mr. P.D. Siwal, Member (Thermal) CEA; Mr. Nico Smith, Chairman SC A1 and Mr. V.K. Kanjlia, Secretary, CBIP, during CIGRE SC A1 Colloquium 26th September 2019 at New Delhi

SC-A1 held its Meeting and Colloquium 2019 at New Delhi from 21st September 2019 to 28th September 2019 in Hotel Taj Vivanta, New Delhi. In beginning of event, a Working Group Meeting of SC-A1/C4 JWG 66 'Guide on the Assessment, Specification and Design of Synchronous Condensers for Power Systems with High Levels of Renewable Generation' was held on 21st September 2019. This meeting was attended by members from USA, UK, Germany, Australia, Hungry, France, Sweden, South Africa and India.

Mr. P.P. Wahi, Director, CIGRE India welcome all delegates and emphasized need of such interactive sessions. He stressed the need of conducting such working group meetings with WEB conference, which will accelerate the progress on Technical Brochure. During meeting emphasis was given on use of Synchronous Condenser to enhance the Electrical System capability in respect of Inertia, Dynamic reactive power compensation, Fault ride through and reactive power support, since the new renewable based power plant fed active power to electrical network through inverters and lacks support to grid on above performance parameters.

On next day 22nd September 2019 an Advisory Meeting with the participation of Chairman, Secretary and Advisory Group Conveners was held from 08:30 to 10:30 hrs.

Group Photo at Guest House, Dadri Power Station

Golf yard on Fly Ash Mound at Dadri Power Station

DADRI POWER STATION VISIT

A full day site visit to Dadri Power Station was arranged 22nd September 2019. Members were shown 500 MW unit of coal based power plant, Combined Cycle Gas based Power Plant, Integrated Solar Thermal Hybrid Plant, which utilise solar thermal energy to heat feed water and enhance efficiency of the thermal power plant. Members were also taken to ash mound, where a thick forest has been developed over Ash Mount with height of 30 metres. This is a unique system for dry ash collection and disposal facility with Ash Mound formation set up for the first time in Asia, which has resulted in progressive development of green belt besides far less requirement of land and less water requirement as compared to the wet ash disposal system.

WORKING GROUP SESSION

The Working Groups discussions were held at Debate Hall, Hotel Taj Vivanta, New Delhi on 23 September 2019. A total of 16 presentations were made on progress of each Working Group by Conveners. The task of following Working Group have been completed and Technical Brochure is published:

- WG.50 Factory quality assurance testing requirements for turbo-generator components - stator bars
- A1.31 State of the art of stator winding supports in slot area and winding overhang of hydro generators
- A1.37 Turbogenerator stator windings support system experience
- A1.39 Dielectric dissipation factor measurements on new stator bars and coils.
- A1.34 Testing Voltage of Doubly - Fed Asynchronous Generator- Motor Rotor Winding for Pumped Storage System

The Six week review of following working group will commenced from October 2019 to February 2020:

- A1.33 Guide for Cleanliness and Storage of Generators
- A1.49 Magnetic Core Dimensioning Limits in Hydro Generators
- A1.42 Influence of Key Requirements to Optimize the Value of Hydro Generators
- A1.54 Impact of Flexible Operation on Large Motors
- A1.53 Guide on Design Requirements of Motors for Variable Speed Drive Application.

ADVISORY GROUP AG A1.01 TURBO-GENERATORS

Convener of following Working Group gave presentation on the progress:

- A1.33 Guide for Cleanliness and Proper Storage of Generators and Components
- A1.48 Guidance on the Requirements for High Speed Balancing / Over-speed Testing of Turbine Generator Rotors Following Maintenance or Repair.

A new working group proposal was presented by Monique Krieg on subject 'Dielectric dissipation factor measurements on Stator Windings'.

ADVISORY GROUP AG A1.02: HYDRO GENERATORS - WG PROGRESS OVERVIEW

Convener of following Working Group gave presentation:

- A1.55 Survey on Split Core Stators

- A1.56 Survey on Lap and Wave Windings and their Consequences on Maintenance and Performance
- A1.59 Survey on Industry Practices and Effects Associated with the Cutting Out of Stator Coils in Hydrogenerators
- A1.60 Guide on Economic Evaluation for Refurbishment or Replacement Decisions on Hydrogenerators
- A1.62 Thrust Bearing For Hydropower – A Survey of Known Problems and Root Causes
- A1.67 State of the Art Methods, Experience and Limits in End Winding Testing for Hydro-Generators

ADVISORY GROUP AG A1.05 NEW TECHNOLOGIES

JWG Convener gave presentation on progress of Joint Working Group SC A1/C4 JWG 66 'Guide on the Assessment, Specification and Design of Synchronous Condensers for Power Systems with High Levels of Renewable Generation'.

ADVISORY GROUP AG A1.06 MOTORS

Presentation on following Working Group was made:

- A1.53 Guide on Design Requirements of Motors for Variable Speed Drive Application
- A1.54 Impact of Flexible Operation on Large Motors
- A1.58 Selection of Copper Versus Aluminium Rotors For Induction Motors
- A1.61 Survey of Partial Discharge Monitoring in Large Motors
- A1.64 Guide for Evaluating the Repair/Replacement of Operable Standard Efficiency Motors
- A1.68 Evaluating Quality Performance of Electric Motor Manufacturing and Repair Facilities.

STUDY COMMITTEE MEETING

The Study Committee meeting was held on 24th September 2019 in hall Tango-2 of Taj Vivanta, New Delhi. Chairman SC-A1 appraise members on the rules and regulations to be followed in CIGRE contributions. The final draft of Minutes of last Meeting in Paris 2018 was accepted by the Committee.

Chairman SC-A1 explained members the description of the structure of Study Committee A1 into Advisory Groups and Working Groups, and the responsibilities of members of SC A1. He presented the complete list of the active Working Groups, currently in progress and newly proposed working groups. Chairman appraised members the methodology to be adopted for preparing Technical Brochure and stated the role of Working Group Conveners:

- Convener is leader of the working group
- He should not do all the work himself

CIGRE Study Committee Meeting on Rotating Electrical Machines (SC A1) in Progress

- All work group members must participate in writing the report or Technical Brochure.
- Working Group Members must Actively contribute to the Work Group by supplying information, completing allocated Chapters, developing conclusions, etc.
- Only contributing Work Group Members will be listed as contributors on the Technical Brochure
- National Committees, Regular Members and Observer Members can indicate experts to participate in Work Groups but Conveners should also identify experts that can actively participate in compiling the works
- Once Questionnaires are complete, it should be send to all Regular and Observer Members to be distributed in their respective country for answering.

The Chairman presents the process of creating a working group, as summarized in this table:

Steps	Activity	Responsibility
1	A new WG is created by means of the Terms of Reference (TOR) that it is sent to the SC Chairman and respective Advisor for comments	WG Convener
2	The TOR is sent to the TC Secretary	SC Chairman
3	The TOR is circulated within the TC for comments from other SC Chairmen with a deadline	TC Secretary
4	Considering the comments received a new version of the TOR is issued	WG Convener & SC Chairman
5	The TOR is sent to the TC Chairman for final approval	SC Chairman
6	The approved final version of the TOR is circulated to the National Committees	Secretary General

CIGRE KNOWLEDGE MANAGEMENT SYSTEM

The Chairman gave a brief summary of the new CIGRE Knowledge Management Systems (KMS) on screen by logging onto the Study Committee A1 Space on the KMS and going through and displaying some of the content (pages) that exist within the Study Committee A1 Space. Such as photos from Paris 2018 meeting, presentations, minutes.

The KMS can be used for the following:

- Work Group Collaboration
- Minutes
- WG Presentations
- Papers

Mr. P.P. Wahi, Director, CBIP, addressing the delegates during Tutorial Session

Mr. Johnn Rocha; Ms. Monique Krieg-Wezelenberg; Mr. Nico Smit, Chiarman, CIGRE SC A1; Mr. Peter Wiehe, Secretary, CIGRE SC A1; Mr. Ben Adams; Mr. Kevin Mayor; Mr. D.K. Chaturvedi, during opening Session for Tutorial

- Contribution presentations
- Photos
- Special Reporter Summary Report

TUTORIALS SESSION

The SC-A1 Tutorial Session on 25th September 2019 in hall Tango 1&2 of Taj Vivanta, New Delhi. There were total four tutorials presented. Tutorial sessions were attended by well over 170 delegates.

TUTORIAL 1 : Magnetic Core Dimensioning Limits in Hydro-generators - *Johnny Rocha, Brazil*

The tutorial first touch upon the fundamentals of magnetic saturation in salient pole machines. While analysing the tutorial appraise on effect of pole shape, speed of machine, stator winding factor etc. on the air gap magnetic flux density. Similar analysis has been done for saturation of stator core, pole and rotor rim.

TUTORIAL 2 : Application of Dielectric Dissipation Factor Measurements on New Stator Coils and Bars - *Monique Krieg-Wezelenberg, Netherlands*

In the field of rotating electrical machines, the Dielectric Dissipation Factor (DDF) measurement is used for assessing the manufacturing quality of individual stator bars/coils and the dielectric behaviour of the electrical insulation system of a winding. To provide a better understanding of the use of DDF measurements in relation to the assessment of the condition and quality of stator insulation systems, 20129 DDF measurements on newly manufactured stator bars or coils concerning four different types of electrical insulation systems were collected and analysed.

Mr. Nico Smith, Chairman SC A1

Mr. V.K. Kanjlia, Secretary, CBIP

Mr. N.N. Misra, Vice Chairman (Tech.), CIGRE India and Mr. M. Roytgarts (Russia) during Technical Session of the Colloquium

TUTORIAL 3 : Guidance on the Requirements for High speed Balancing/Over Speed Testing of Turbine Generator Rotors following Maintenance or Repair - *Ben Adams, United Kingdom*

The tutorial pertains to turbo-generator balancing requirement after repairs. The issue of balancing a turbo-generator rotor (2P and 4P) after repair/ rewind was discussed in the Working Group. The results have been deliberated in the Tutorial. The challenge is due to the geographic distance between the balancing facility and the Site and cost overruns in transport and logistics have been indicated by the speaker. It is fairly agreed that if new copper is not used during rewind/ repair, high speed balancing is not a recommendation.

TUTORIAL 4 : Guide for Cleanliness and Proper Storage of Generators and Components - *Kevin Mayor, Switzerland*

The tutorial define methodology for storage of critical components of generator to guide utilities not sure on adequacy of present procedures. It emerged from study that foreign particles including dust can clog the ducts and may cause electric shorts. Specific discussion was carried out for storage of complete stator, complete rotor, stator bars, rotor bars and insulating materials. Clean conditions, access control, proper usage of desiccant, dehumidifiers are to be given due care. The Working Group has systematically organised the details making it a ready guide for utilities.

COLLOQUIUM

The SC-A1 2019 Colloquium on 26th & 27th September 2019 in hall Tango 1&2 of Taj Vivanta, New Delhi. There were total 24 papers were presented. Colloquium sessions were attended by 185 delegates. The program began with lighting up the lamp ceremony. During inaugural session, President, CIGRE India stressed need of using high

A recognition from CIGRE India for exceptional contribution by Mr. A.K. Gupta, Director, NTPC and Mr. D.K. Chaturvedi, Former GM, NTPC in CIGRE activities of SC-A1

A view of the participants

efficiency machines to reduce electricity consumption and role of large turbo-generators as Synchronous Condenser for enhancing electrical network reliability and efficiency – a step towards Greening the Grid.

First Technical Session began with a lead paper 'Electrical Machines Trends in Renewable Mix Scenario, GHG Emission Reduction and High Reliability' presented by Mr. A.K. Gupta, Vice President, CIGRE India. The paper emphasized need to contribute more towards better environment through improved efficiency and reliability of electrical machines.

He appraise delegates on phasing out of inefficient thermal plants and introduction of large-scale renewable generation in the grid forcing fossil fuel based power plant operation on cyclic duty. He emphasized on development of new designs and solutions to handle the thermal stress coming on the machine due to cyclic loading.

It was also suggested to explore possibility of using our retired machines as Synchronous Condenser, which might find a wide application due to large renewable penetration in the grid. These synchronous condensers will help in grid stability during sudden load changes. Important requirements of maintaining grid inertia, Short Circuit withstand capability and dynamic voltage withstand capability can be very well meet by Synchronous Condenser.

In view of high renewal penetration in near future, the preferential subjects for SC-A1 2019 Colloquium were finalized as follows:

Preferential Subject 1: High Renewable Penetrated Networks

(a) Methods and experiences for the evaluation of existing base load plant to handle new grid requirements such as cyclic loads, high values in the rate of change of frequency (Hz/s), fault ride through capability, extended U/f requirements, higher power factor requirements.

(b) Usage of new as well as decommissioned power plant generators as synchronous condensers to solve power quality issues due to large scale renewable integration & comparison with other FACTs devices.

(c) Design improvements, technological advancement and operational experience of Hydro generators for prolonged and efficient operation as low and very low speed generators, synchronous condensers and pump-motors.

(d) Innovative trends in the field of Turbo generators, Hydro generators, wind turbine generators, large motors and high efficiency motors.

(f) Suitability of generators and motors in a renewable energy mix environment from a harmonics point of view.

(g) Latest designs implemented or proposed for Rotating Electrical Machines to endure severe load cycling.

(h) Wind Turbine generator experience: Failures, design challenges, maintenance philosophies and maintenance challenges.

Delegates at 800 kV HVDC Terminal, Agra

(i) Concentrated solar power, solid waste and Biomass power plants: Design, specification, construction, efficiency, operation and maintenance experience.

Preferential Subject 2: Operational Experience and New Developments

(a) Operational experience on state of the art technologies used for large turbo generators, hydro generators, wind turbine generators, high voltage motors and high efficiency motors.

(b) Latest designs and maintenance practices to improve efficiency, reliability, availability, robotic inspections, and reduce maintenance costs.

(c) Performance and reliability comparison of different designs of large motors of same ratings and duty cycles with regards to heating, efficiency, mean time to failure, life cycle costs.

(d) Advanced and optimised condition monitoring and analysis making use of latest technologies, taking digitization, big data, advanced analytics, etc. into consideration.

(e) Experience with renovation, modernization and up-rating of aged power plants.

(f) Novel techniques to overcome known operational and design problems of hydro power plants especially for operation in silt prone water.

There were 24 papers presented covering large turbo generators, machine insulation system, hydro generators and motors. These papers were presented in six sessions on 26th and 27th September 2019.

TECHNICAL VISIT

A technical visit was arranged on 28th September 2019 to +800 Multi terminal HVDC station near Agra. Delegates were given a detailed presentation on the +800 kV, 6000 MW HVDC Bi-pole Transmission between Biswanath Chariyali (Assam) to Agra (Uttar Pradesh). Later delegates were shown +800 HVDC control room and equipments.

CULTURAL EVENING

A cultural evening was organized on 26th September 2019 evening at Hotel Taj Vivanta New Delhi.

Glimpses of Cultural evening held on 26th September 2019

CIGRE Joint Tutorials

Transformers (SC-A2), Overhead Lines (SC-B2) and Materials & Test Techniques (SC-D1)

(Under the aegis of CIGRE SC A2; B2 and D1)

20 November 2019 at New Delhi, India

A : Eight Tutorials jointly held on the subject of three CIGRE Study Committees

Faculties for Tutorials on Transformers

Mr. R.K. Tyagi, CGM POWERGRID

Prof. S.V. Kulkarni, IIT Mumbai

Ms. Tara Lee, Australia

Faculties for Tutorials on Overhead Lines

Mr. Pierre Van Dyke

Mr. Peter Dulanthy

Faculties for Tutorials on Materials

Dr. Jens Seifert

Dr. Ralf PIETSCH

TRANSFORMERS - (CIGRE-SCA2)

Tutorial 1 : Bushing Failure Mode Analysis – *Mr. R.K. Tyagi, Chief GM, POWERGRID Corporation of India*

Tutorial 2 : Latest Trends/ Advances in Transformer Design - *Prof. S.V. Kulkarni, IIT Mumbai, India*

Tutorial 3 : Health Indexing - *Ms. Tara-Lee, MacArthur, Australia.*

OVERHEAD LINES - (CIGRE-SCB2)

Tutorial 4 : Use of Robotics in Inspection and Maintenance of OHLs – TB 731, 2018 – *The tutorial has been cancelled due to unavailability of the presenter*

Tutorial 5 : Experience with the Mechanical Performance of Non-Conventional Conductors - TB 695, 2017 - *Mr. Pierre Van Dyke, Canada*

Tutorial 6 : Transmission Line Structures with Fiber Reinforced Polymer - FRP, WG B2.61, 2018 - *Mr. Janos Toth- Presented by Mr. Peter Dulhunty (Australia)*

MATERIALS & TEST TECHNIQUES - (CIGRE-SCD1)

Tutorial 7 : New Insulating Materials – *Dr. Jens Seifert (DE), Germany*

Tutorial 8 : High-Voltage On-Site Testing with Partial Discharge Measurement - *Dr. Ralf PIETSCH, Germany*

CIGRE Joint Colloquium

Transformers (SC-A2), Overhead Lines (SC-B2) and Materials & Test Techniques (SC-D1)

(Under the aegis of CIGRE SC A2; B2 and D1)

21-22 November 2019 at New Delhi, India

Dignitaries on the Dais during inaugural session of the colloquium

CIGRE India hosted annual meeting of CIGRE Study Committee A2 on Transformers; B2 on Overhead Lines and D1 on Materials & Test Techniques and its various Working Groups at New Delhi, India from 16-18 November 2019. In conjunction a Joint Tutorials on 20th November 2019 & parallel colloquium on these three Study Committees A2; B2 & D1 were also held on 21-22 November 2019.

During the Common opening session of the colloquium on 21 November 2019, number of prominent Government officials & industry figures from India and also the chair and secretary of the Indian National Committee addressed the participants. Mr. P.P. Wahi, Director, CIGRE-India proposed vote of thanks. Dr. Konstantin Papaillou, Former Chairman, CIGRE SC B2 also addressed during opening session.

CIGRE-India Awards

Special Appreciation Awards were presented during opening session to the following for their excellent contribution in CIGRE activities at National & International level.

1. Mr. I.S. Jha, President CIGRE-India & CIGRE Steering Committee Member from India
2. Ms. Seema Gupta, Chairperson for CIGRE NSC A2, and Women in Engineering Forum
3. Mr. R.P. Sasmal, Chair-Tech, CIGRE-India
4. Mr. N.N. Misra, Vice Chair-Technical, CIGRE- India
5. Mr. Anish Anand, Chairman CIGRE NSC B2


International Tutorials & Colloquium
Latest Trends and Innovations on


International Tutorials & Colloquium
Latest Trends and Innovations on
International Tutorials & Colloquium
Latest Trends and Innovations on


International Tutorials & Colloquium
Latest Trends and Innovations on

B (i) Summary Report of the Technical Sessions for colloquium on SC A2 on Transformers

A special theme address for Study Committee A2 was delivered by Ms. Seema Gupta, the Observer Member for India in Study Committee A2. She explains the main challenges facing transformer engineers in India.

- **Preferential Subject 1** for Study Committee A2 was "Advances in Transformer Design, including use of new materials". The session co-chairs were Mr. Jan HAYEK and Mr. Virenda LAKHIANI. The keynote address was given by Mr Martin STOESSL, who emphasised some of the points made previously in the special opening address. A total of 13 papers were presented for this Preferential Subject. Subjects for the papers included applications and design concepts (3); improvements in transformer design (4); improvements in modelling (3); use of new materials (2); and risk assessment methodologies (1). The session co-chairs selected the following as the best paper in this Preferential Subject: "Patrice HURLET, "Improvement of transformer specification to enhance reliability of key power transformers (GSU for nuclear power plants)"

  The following paper was also highly commended by the Study Committee chairman:

  "Pramod RAO et al, "Transformer bushings: current technology trends, development and its relevance in monitoring bushings in service"

- **Preferential Subject 2** for Study Committee A2 was "Quality Assurance and Short-Circuit Withstand Capability of Transformers". The session co-chairs were Mr. Henk FONK and Mr. R.K, TIWARI. The keynote address was given by Mr. P. RAMACHANDRAN, who used his experience to explain developments in the short-circuit withstand capability of transformers from 1885 to the present day. He suggested that short-circuit type test reports for power transformers should be valid for 10 years. He also suggested that transformer operators should consider ordering a short-circuit test for series of more than 10 transformers. A total of 8 papers were presented in this Preferential Subject. Subjects for the papers included improvements in transformer construction (2), improvements in transformer safety (1), and short-circuit withstand capability (5). The session co-chairs selected the following as the best paper in this Preferential Subject:

  "Professor Vasily LARIN et al, "Russian practice on tests and confirmation of power transformers ability to withstand short-circuits"

- **Preferential Subject 3** for Study Committee A2 was “Operational Experience in the Field of Transformers”. The session co-chairs were Dr Patrick PICHER and Dr Aradhana RAY. The keynote address was given by Dr BN DE BHOWMICK, who gave more details on the main challenges facing transformer engineers in India and recent steps taken to meet them. A total of 10 papers were presented in this Preferential Subject. Most of the papers were on the subject of transformer field testing (7). The session co-chairs selected the following as the best paper in this Preferential Subject: “Professor Stefan TENBOHLEN et al, “UHF sensor placement on power transformers for PD monitoring”

Closing remarks were made by Ms. Seema GUPTA, the Observer Member for India in Study Committee A2, and by Mr. P.P. WAHI, Director of CBIP and CIGRE-India. Special thanks were given to Mr. Vishan Dutt of CBIP, for his role in organising the Joint Colloquium.

B (ii) Summary Report of the Technical Sessions for colloquium on SC B2 on Overhead lines

A theme address for Study Committee B2 was delivered by Mr. Anish Anand, Member for India in Study Committee B2. A special Address on "The Truth about EMF and Health" was delivered by Dr. Konstantin Papailliou, Former Chairman, CIGRE SC B2

- **Preferential Subject 1** for Study Committee B2 was "Design Optimization and New Lines". The session co-chairs were Mr. Herbert Lugschitz, Chair, CIGRE SC B2 and Mr. Anish Anand, Sr. GM, POWERGRID, India. The keynote address was delivered by Mr. Wolfgang Troppauer (AT)
- **Preferential Subject 2** for Study Committee B2 was "Reliability and Economics, Maintenance". The session co-chairs were Mr. Oswaldo Regis (Brazil), and Mr. R.P. Sasmal, Tech. Chair, CIGRE -India. The keynote address was given by Mr. Pierre van Dyke (CA)
- **Preferential Subject 3** for Study Committee B2 was "New Materials and Products for Use on OHLs, Diagnostics". The session co-chairs were Mr. Vivek Chari (IN), Mr. B.N. De. Bhowmick, ED, POWERGRID and Mr. Herbert Lugschitz, Chair, CIGRE SC B2. The keynote address was delivered by Mr. John McCormack (AU)

Total 19 presentations, presented in three sessions besides one theme paper for each of the session

Out of 19 presentations 13 were from INDIA and one each from Australia, Belgium, Hungary, Korea, Canada and Slovenia.

At the end of each presentation there was a very informative and interesting discussions. Various clarifications were asked by the participants and clarified by the presenters very effectively and nicely.

Two days Technical Program closed with thanks conveyed to everyone i.e presenters, participants' Joint Chairs and organizers.

B(iii) Summary Report of the Technical Sessions for colloquium on SC D1 on Materials & Test Techniques

A theme address for Study Committee D1 was delivered by Dr. B.P. Muni, GM, BHEL. He emphasized the current status of India's power capacity and consumption per capita with forecasted demand of electrical power equipment in a context to global demand.

- **Preferential Subject 1** for Study Committee D1 was "Long Term Performance of Insulation Systems (AC and DC)". The session Chairs were Dr. Ralf Pietsch (DE) and Dr. Joy Thomas, IISc Bangalore.
- **Preferential Subject 2** for Study Committee D1 was "Test techniques for UHV including HVDC". The session Chair were Dr. Ralf Pietsch (DE) and Dr. Sukumar Roy, AGM, BHEL
- **Preferential Subject 3** for Study Committee D1 was "Advanced Diagnostic Techniques". The session Chair was Dr. Ralf Pietsch (DE) and Dr. Muni, GM, BHEL.

Total 15 presentations, presented in three sessions including one Theme paper. Out of 15 papers 5 from INDIA including one base paper 3 were from GERMANY, 2 from SWITZERLAND, one each from ISRAEL, BRAZIL, JAPAN, SERBIA and NETHERLANDS.

At the end of each presentation there was a very informative and interesting discussions. Various clarifications were asked by the participants and clarified by the presenters very effectively and nicely.

There was a perfect time management by the joint chairmen. Two days Technical Program closed with thanks conveyed by Dr. Ralf Pietsch to everyone i.e. presenters, participants and organizers. At last Mr. S.K. Lamba, Advisor (CBIP) thanked Dr Pietsch for conducting chairing all the three sessions. He thanked all the presenters and organizers.

Glimpsis of CIGRE Study Committee Meetings at New Delhi (India)

CIGRE SC A2 Meeting

CIGRE SC D1 Meeting

CIGRE SC B2 Meeting

Glimpsis of Cultural Evening and Gala Dinner organised on 21st November 2019 for the Participants

Glimpsis of Technical Visit to 800 kV HVDC terminal at Agra

Visit to Taj Mahal

Activities of CIGRE India

About CIGRE-India

CIGRE-India functions as the National Committee for CIGRE and coordinates CIGRE activities in India. It Organizes National Study Committee (NSC) meetings and Events at National Level. Affairs of CIGRE-India are administered by the General Body / Governing Council

Governing Body of CIGRE India

President	: Mr.I.S.Jha, Chairman & Managing Director, POWERGRID
Vice President	: Mr. A.K. Gupta, Director, NTPC
	: Ms. Seema Gupta, Director, POWERGRID
	: Mr. S. Balakrishnan, Director, BHEL
	: Mr. Harish Agarwal, President IEEMA
Technical Chair	: Mr. R.P. Sasmal, Former Director, POWERGRID
Vice Chair-Tech.	: Mr. N.N. Misra, Former Director, NTPC
Secretary& Treassurer	: Mr. V.K. Kanjlia, Secretary, CBIP
Director, CIGRE India	: P.P. Wahi, Director, CBIP

CIGRE AORC

- CIGRE-India had a privilege to Chair CIGRE-AORC During 2016-18.

  Dr. Subir Sen, was, Chairman of CIGRE-AORC and Mr. P.P. Wahi was the Secretary.

  CIGRE-India Conducted CIGRE-AORC Administrative Meeting at New Zealand in Sept 2017 and at Paris in August 2018. We also organized CIGRE-AORC Technical meeting at Gangtok, Sikkim, India in May 2018.

MAJOR ACTIVITIES OF CIGRE – INDIA DURING 2019

1. **Growth of Membership**

   In the year 2016 - 594 nos. equivalent members and

   In the year 2017 - 768 nos. equivalent members

   In the year 2018 - 827 nos. equivalent members

   In the year 2019 – 827 nos. equivalent members

   Student Membership : 95 Nos.

2. **Participation in CIGRE Study Committee meeting at various places in the world:**

   All the study committees were attended by its members / representatives except SC B1on HV Insulated cables.

   List of participants in CIGRE Study Committee at various placed from India since 2016 is attached as Annexure 1

3. **CIGRE Study Committee Meetings held in the recent past, proposed in India and status of approval by CIGRE**

D2 - Information & Telecommunication	Held in 2013
B4 – DC Systems and Power Electronics	Held in 2015
B1 - HV Insulated Cables	Held in 2017
A1 - Rotating Machines	Held in 2019
A2 - Power Transformers & Reactors	
B2 - Overhead Lines	
D1 - Materials & Emerging test Techniques	
B5 - Power System Protection & Automation	Allotted in 2021
A3 - T & D Equipment	
B3 - Substations & Electrical Installations	Proposed in 2023
C2 - Power System Operation and Control	
C4 - Power System Technical Performance	
C1 - Power System Development & Economics	Proposed in 2025
C6 - Active Distribution systems & Distributed Energy Resources	

4. **CIGRE Session 2020 – Strategy for participation**

   (i) Total 240 abstracts were reviewed. Synopsis accepted – 37 Nos. out of 45 recommended (List attached- Annexure 2). Full papers to be submitted to Paris by 14th Feb 2020.

   (ii) NGN – Papers for CIGRE session 2020 :

   - A call for synopsis from young engineers have been received from Paris

- CIGRE India is entitled to send four abstracts each on different study committee.
- We have sent our consent to participate before 6th December and names to be sent by 14TH FEB. 2019.

(iii) Participation in CEO Meet at Paris on 24 August 2020

The Following Were Proposed for participation from India :

1. NTPC - CMD
2. POWERGRID - CMD
3. Sterlite - Mr. Prateek Agarwal
4. POSOCO – Mr. K.V.S. Baba
5. Tata Power - Mr. Praveer Sinha,

Invitation letter are being sent to above officers by CIGRE Paris

(iv) Participation in Workshop in Grid Disturbance - Last Date for submission of presentation is 16 March 2020

Mr. K.V.S Baba, CMD, POSOCO & Mr. S.K. Chateerjee, Chief (regulations), CERC has been requested to prepare a presentation for this workshop from India.

(v) Reaction to Key note speech by India during Opening Panel on 24th AUGUST 2020

Name of Madam Seema Gupta, Director PowerGrid has been proposed from India

(vi) India Pavilion in 2020 : Invoices already Sent to all concerned by CIGRE.

Space directly booked by	• Scope (12 sqm)	12 sqm
Participation Confirmed & Space booked	• KEI (18 sqm); • Taurus (9 sqm) • Modern Insul. (9 Sqm)	36 sqm
	• IEEMA (45 sqm)	45 sqm
	• NTPC- 18 sqm • BHEL – 9 sqm • PowerGrid – 12 sqm	39 sqm
Total Space	132 sqm.	

5. CIGRE-India - Women in Engineering Forum

- o 1st meeting held on 18/10/2019 at Power Grid
- o 2nd Meeting was held on 19/11/2019 at Hotel Royal Plaza

6. NGN Forum of CIGRE India : Being constituted

7. Steering Committee Meeting – Nov. 2020

- The dates proposed and notify on KMS are 16-20 Nov. 2020 at Goa
- A symposium on Renewable integration including energy storage is also to be planned.

8. Representative on Study Committee for 2020-22 from India.

The proposal from India being finalised from India and to be sent to Paris by 15.01.2020

9. Distinguished Membership Award of CIGRE for 2020 – Proposal to be sent to 15.02.2020

10. CIGRE fellow Award from India – Proposal to bent by 30 .04.2020

11. CIGRE Events held in India in 2019

- Meeting & Intl. Conf. of SC A1 on Rotating Machines - proposed from 23 - 28 Sept. 2019 at New Delhi.
- Meeting & Intl. Conf. of three Study Committee i.e. SC A2 (Transformers)/ B2 (Overhead Lines) /D1(Materials) – in 18-23 Nov. 2019 in New Delhi.
- CIGRE-India plan to hold minimum one event by each National Committee (tutorials /workshop/ conferences) in a year at National Level.

12. CIGRE-India - Events Planned

(i) Conference on HV cables, Installation, O&M and field Experience - 19-20 Feb. 2019 at New Delhi.

(ii) International conference on Renewable Energy- Issues & Challenges including Energy Storage. – 23-24 April 2019 at Vadodara

(iii) CIGRE

(iv) Conference on Power Sector Development – Modern Trends & Innovations at International Level on 23-24 July 2020, New Delhi

(v) CIGRE Session at Paris – 23-28 August 2020

(vi) International Conference on Renewable integration including energy storage – 16-20 Nov. 2020

(vii) CIGRE SC B5 Colloquium in India - Sept. 2021

(viii) CIGRE SC A3 Colloquium in India - Nov. 2021

CIGRE- India launches its Women in Engineering (WIE) forum on 18 Oct. 2019

CIGRE-India launces Women in Engineering (WIE) forum on 18.10.2019. Ms. Seema Gupta, Vice President, CIGRE-India and Director (Operation) Power Grid has consented to lead the WIE forum of CIGRE-India as its Chairperson. She addressed the participants during the occasion. Besides Mr. I.S. Jha, President CIGRE-India & Hon'ble Member, CERC, Mr. R.P. Sasmal, Technical Chair, CIGRE-India, Mr. K. Srikant, CMD, POWERGRID, Mr. R.K. Chauhan, Director (Projects), POWERGRID, Mr. V.K. Kanjlia, Secretary, CIGRE India and Mr. P.P. Wahi, Director, CIGRE-India addressed the participants.

I.S. Jha
President, CIGRE-India

K. Srikant
CMD, POWERGRID

R.P. Sasmal
Chairman –Tech., CIGRE-India

V.K. Kanjlia
Secretary, CIGRE India

R.K. Chauhan
Director (Projects) POWERGRID

P.P. Wahi
Director, CIGRE-India

Vision of the Forum

CIGRE WiE is a forum for women engineers to interact, develop their careers, increase their self-confidence, improve their professional skills.

Mission of the Forum

CIGRE WiE inspires, motivates women engineers by helping to provide links to global thought leaders and role models, as well as to demonstrate the influence and functions of female professional communities.

Around 100 Women Engineers participated from 25 different organisations on 18.10.2019

Glimpsies of Meeting of Women in Engineering Forum of CIGRE-India on 19-11-2019, New Delhi

Madam Seema Gupta, Chairperson, CIGRE- India WIE Forum, addressing the participants. Ms. Khayakazi Doika, Global Chairperson for CIGRE Women in Engineering and Ms. Terr Lee from Australia is also gracing the Dias.

Ms. Tara Lee (Australia), Moderator for the Session Addressing the Participants

Ms. Khayakazi Doika, CIGRE WIE Chair, is addressing the participants

Ms. Rachana Garg - IEEE India WiE Vice Chair, addressing the participants

Ms. Sunita Chauhan, Sr. CIGRE member from India addressing the participants

A view of the participants

Mr. P.P. Wahi, Director, CIGRE-India during inaugural session

Group Photograph

Annexure 1

Participation in CIGRE Study Committee Meetings Since 2016

Study Committee (SC)		2016 - at Paris in August 2016	2017		2018 - at Paris in August 2018	2019	
			Date & Venue	Participants		Date & Venue	Participants
1	**A1: Rotating Machine**	Mr. D.K. Chaturvedi, NTPC	18-23 Sept.17 Vienna, Austria	Mr. D.K. Chaturvedi, NTPC	Mr. D.K. Chaturvedi, NTPC Mr. N.N. Misra, CIGRE India	24 Sept. 2019 New Delhi	Mr. D.K. Chaturvedi NTPC
2	**A2 : Transformers**	Ms. Tanavi Srivastava, Alstom	29 Sept. to 6th Oct. 2017, Poland	Mr. B.N. De Bhowmick	Mr. Selvakumar P. Victor, PG	19th Nov. 2019 New Delhi	Ms. Seema Gupta, POWERGRID
3	**A3 : High Voltage Equipment**	Mr. N.N. Misra, CIGRE-India	30 Sept. – 6th Oct. 2017, Canada	R.K. Tyagi, PG	Mr. N.N. Misra and Mr. R.P. Sasmal, CIGRE -India	7-13 Sept. 2019 Bucharest Romania	Mr. R.K. Tyagi, PG and Mr. Rakesh Kumar, PG
4.	**B1 : HV Insulated Cables**	Mr. Dipal Shah, Pfistrer	9-13 Oct. 2017 India	Mr. Dipal Shah	Mr. Lalit Sharma, KEI and Mr. Dipal Shah	9th Sept. 2019 (Denmark)	Nil
5	**B2 : Overhead Lines**	Mr. Gopal Ji, POWERGRID	29-30 May 2017 Dublin, Ireland	Prof. C. Johnson Excel Engg. college	Mr. A..K. Vyas, PG	19 Nov. 2019 New Delhi	Mr. Anish Anand, PG
6	**B3 : Substations**	Mr. Abhay Choudhary, POWERGRID	Sept. 2017 Brazil	Mr. Rajil Srivastava, PG	Mr. R.P. Sasmal, CIGRE-India and Mr. Rakesh Kumar,	20-25 Sept. 2019 China	Mr. Raji Srivastava, PG & Mr. Abhay Kumar, PG
7	**B4 : HVDC Link and AC Power Electronic Equipment**	Shri R.K. Chauhan, PowerGrid	30 Sept. – 6th Oct. 2017 Canada	Shri R.K. Chauhan PG	Nil	28-30th Sept 19, 1-5th Oct 2019- South Africa	Mr. R.K. Chauhan, Dir, PG and Mr. B.B. Mukharjee, PG
8	**B5 : Power System Protection and Local Control**	Mr. Subhash Thakur NTPC	Sept. 2017 New Zealand --	Mr. Subhash Thakur NTPC	Mr. Subhash Thakur	24-28th June 19 Norway	Mr. Abhishek Khanna, Mr. Debashish Dutta, Mr. Anand Pandey, NTPC
9	**C1 : Power System Planning and Development**	Ms. Seema Gupta, PowerGrid	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. R.K. Verma and Mr. R.P. Sasmal, CIGRE -India	20-26th Sept. 2019 Chengdu, China	Ms. Seema Gupta, POWERGRID and Mr. Ashok Pal, PG
10	**C2 : Power System Operation and Control**	K.V.S. Baba POSOCO	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. P.K. Agarwal	4-7th June 2019 Aalborg, Denmark	Mr. KVS Baba, POSOCO
11	**C3 : System Environmental Performance**	**Nil**	Sept. 2017 Seoul, Korea	Mr. K.V.S. Baba, POSOCO	Nil	4-7th June 2019 Aalborg, Denmark	Mr. B.N. De Bhowmick, PG
12	**C4 : System Technical Performance**	Mr. N.M. Seth, GETCO	May 2017 Dublin, Ireland	Mr. K.V.S. Baba, POSOCO	Mr. Selvakumar P. Victor,	4-7th June 2019 Aalborg, Denmark	Mr. B.B. Chauhan, GETCO
13	**C5 : Electricity Markets and Regulation**	K.V.S. Baba, POSOCO	May 2017 Dublin, Ireland	Mr. S.C. Saxena, POSOCO	Mr. P.K. Agarwal	16-19th Sept19 Canada	Mr. P.K. Agarwal, POSOCO
14	**C6 : Distribution Systems and Dispersed Generation**	Dr. Subir Sen, POWERGRID	May 2017 Dublin, Ireland	Mr. S.C. Saxena POSOCO	Nil-	(3-6 June 2019) Aalborg, Denmark	Dr, Subir Sen, PG and Mr. Rajesh Kumar, PG
15	**D1 : Material for Electro technology**	Mr. Jithinsunder, BHEL	30 Sept. – 6th Oct. 2017 Canada	Nil	Mr. Jithinsunder, BHEL	18-23 Nov. 2019 New Delhi	Mr. B.P.Muni, BHEL
16	**D2 : Information Systems & Telecommunications for System**	N.S. Sodha, PowerGrid	20-22 Sept. 2017 Moscow	Mr. N.S. Sodha	Mr. N.S. Sodha	11-14th June 2019 Helsinki, Finland	Mr. N.S. Sodha

Annexure 2

S.No.	Group	PS	Organisation	Title	Selected/Not Selected
1.	A1	PS3	NTPC Limited	Failures of Large Turbo-Generators on Prolonged Site Storage - Case Studies of Indian Power Utility	Selected
2.	A1	PS2	Tata Power Mumbai	Pd Measurement of Rotating Machine For Condition Monitoring	Selected
3.	A2	PS3	CTR Manufactures	Reliability Evaluation of Ester Oil Filled Onload Tap Changers Through Critical Tests	Selected
4.	A2	PS3	GE	An Innovative Solution to Assess The Reliability of Transformers by Integrated Transformer Health Monitoring – A Pilot Project in GETCO	Selected
5.	A2	PS3	Power Grid Corporation of India	Powergrid's Leap Towards Intelligent Condition Monitoring of Assets	Selected
6.	A3	PS2	Tata Power Delhi Distribution Ltd.	Approach & Experience of Iot Based Predictive Maintenance Technologies in Power Distribution Network	Selected
7.	A3	PS1	Power Grid Corporation of India	Case Study – Improving Reliability of Circuit Breaker by Using Controlled Switching and Removing Pre Insertion Resistor (PIR)	Selected
8.	B1	PS2	Tata Power Mumbai	Power Cables Insulation & Establishing Relationship Between Insulation Level Selection and Aging	Selected
9.	B1	PS2	BHEL	Design and Development of Back-To-Back Gas-to-Cable Termination for 420 kv Gas Insulated Switchgear	Selected
10.	B2	PS2	Sterlite Power Transmission Ltd.	Experience of Live Line or Zero Shutdown Reconductoring In India	Selected
11.	B2	PS1	Adani	Indian Experience of Refurbishment Of Tower Foundation Located In Water Bodies	Selected
12.	B3	PS2	GETCO	Maintenance, Monitoring & Strengthening of Substation Grounding – Experience of GETCO	Selected
13.	B3	PS2	ABB	Aeolian Vibration Challenges at Renewable Substation	Selected
14.	B4	PS1	GE	Fundamental Frequency Blocking Filters In HVDC Schemes- Design Considerations and Practical Case Study	Selected
15.	B4	PS3	Power Grid Corporation of India	Operational Experiences and Study of STATCOM for Emerging Grid with Renewable Power Network	Selected
16.	B5	PS2	ABB	Experience in Communication Network Design for High Performance Requirements in IEC 61850 Process Bus Based Substation	Selected
17.	B5	PS2	Power Grid Corporation of India	Engineering and Management of Communication Networks in Powergrid's First Digital Substation	Selected

18.	C1	PS1	Power Grid Corporation of India	Development of Power Transmission System Interconnections in South-Asian Region	Selected
19.	C1	PS1	Power Grid Corporation of India	Fault Current Limiter Using Series Reactors in Indian Power System	Selected
20.	C2	PS3	GETCO-SLDC	System Operation Challenges with Large and Distributed Generators	Selected
21.	C2	PS1	POSOCO	Capacity Building of Indian System Operators In The Emerging Environment	Selected
22.	C2	PS3	Scope T&M Pvt. Ltd.	System Operation Challenges for Distributed Wind Power Resources in India – A Case Study	Selected
23.	C2	PS3	POSOCO	Lift Irrigation Projects for Better System Operation Under High Renewable Energy Penetration	Selected
24.	C2	PS1	POSOCO	Use of Meteorological Radar Image To Improve Resiliency Of Indian Grid	Selected
25.	C3	PS2	Power Grid Corporation of India	POWERGRID's Experience on Electric and Magnetic Field Induction Under 765/400 Kv Power Transmission Lines	Selected
26.	C4	PS3	POSOCO	Power Quality Monitoring of HVAC Solar Power Station Using Sequence Voltages from Synchrophasor – A Case Study	Selected
27.	C4	PS1	GETCO	Implementation of Emerging Techniques & Tools For Reliability, Stability And Flexibility of RE Rich Modern Power Grid With Multidimensional Approach – Indian Grid Context	Selected
28.	C5	PS1	POSOCO	Implementation of Security Constrained Economic Despatch Pan India	Selected
29.	C5	PS1	POSOCO	Experience of Implementation of Reserve Regulation Ancillary Services And Fast Response Ancillary Services In India	Selected
30.	C5	PS1	POSOCO	Transition from Administered to Market Linked Imbalance Handling Mechanism in Indian Electricity Market	Selected
31.	C6	PS2	Power Grid Corporation of India	Tapping of Power from overhead Earthwire of EHV Transmission Line to Supply Remotely Located Load-Powergrid Experience	Selected
32.	D1	PS3	IIS-Bengaluru	Erosion Performance of Boron Nitride Filled Silicone Rubber Composite as an Outdoor Insulator Weathershed Material	Selected
33.	D1	PS2	ERDA	Analysis of 400 kV Failed Silicone Rubber Insulators: Role of Micro-Cracks in Glass Fiber Rod and Electric Field Distribution in Failure Mechanism-Case Study	Selected
34.	D2	PS1	ISGF	Smart Grid Developments In India	Selected

35.	D2	PS1	POSOCO	Impact of Big Data, Internet of Things and Analytics in Indian Power System - A Case Study	Selected
36.	D2	PS2	Scope T&M Pvt. Ltd.	Cyber Secured Grid Operations with Machine Learning & Artificial Intelligence Implementation-A Case Study	Selected
37.	D2	PS1	POSOCO	Facilitating Power Banking and Overarching Arrangement through Smart Contracts Based on Block Chain Technology	Selected
38.	A1	PS3	NTPC	Design Improvement to Address Large Motor Termination Failures - Utility Perspective	Not Selected
39.	A3	PS1	ERDA	Development of Silver-Carbon Nano Tube Contact Tips and Study of Their Properties and in Service Performance	Not Selected
40.	A3	PS2	BHEL	Optimization for Economic Design of Isolated Phase Bus Ducts: Simulations and Field Testing - A Case Study	Not Selected
41.	B1	PS2	NHPC Ltd.	400 kV Oil Filled Cables: Experience of Two Decades with EHV Cables	Not Selected
42.	B2	PS2	Aditya Birla	Testing of RTV Coated Porcelain Disc Insulators and Their Use in The Indian Power Sector for Enhancing Network Performance	Not Selected
43.	B4	PS3	Siemens	Stability Improvement of Grid With SVC Controller & Comparison Between Rtds Simulations with Actual Scenario	Not Selected
44.	B5	PS1	NTPC Ltd.	Integration of Testing Methodology of Numerical Relays with Life Cycle Management of All Protection IEDS in Utility System – NTPC Experience	Not Selected
45.	C2	PS1	POSOCO	Primary Frequency Response in Indian Grid: An Experience of Two Decades	Not Selected

CIGRE Members from India in 2019

(As on December 2019)

Institutional Members

S. No.	Organisation
1	Andhra Pradesh Electricity Regulatory Commission
2	Bihar Electricity Regulatory Commission
3	Central Electricity Regulatory Commission
4	CIGRE-India - COE,Centre of Excellence
5	Delhi Electricity Regulatory Commission
6	Electrical Research and Development Association
7	Gujarat Electricity Regulatory Commission
8	H P Electricity Regulatory Commission
9	IEEMA
10	Indian Inst. of Technology Kanpur
11	Indian Institute of Technology Bombay
12	Jharkhand State Electricity Regulatory Commission
13	Joint Electricity Reg. Com.-for Goa &Uts
14	Maharashtra Electricity Regulatory Commission
15	Malaviya National Inst. of Tech., Jaipur
16	National Institute of Technology, Calicut
17	Punjab State Electricity Regulatory Commission
18	Ramelex Testing & Research Institute
19	Sikkim State Electricity Regulatory Commission
20	U.P. Electricity Regulatory Commission
21	Uttarakhand Electricity Regulatory Commission
22	West Bengal Electricity Regulatory Commission

Individual Members

S. No.	Name	Organisation
1	ABB	Gaurav Kumar Kasal
2	ABB Global Industries & Services Ltd.	Sachin Srivastava
3	ABB India Ltd.	Biplob Sardar
4	Adani Electricity Mumbai Limited - Trans	Arvind Kumar Sharma
5	Adani Power Maharashtra Ltd.	Niraj Agrawal
6	Adani Transmission Ltd,	Bipin B Shah
7	Adishaktyai- India	Neeraj Khare
8	Alfa Consultants	Ramesh Dattaraya Suryavanshi
9	Amara Raja Power Systems Ltd	Venkata Krishna Marmavula Muni
10	Angelique International Limited	Gopal Ji
11	Anna University	Usa Savadamuthu
12	Apar Industries Ltd.	Srimanta Kumar Jana
13	Avaada Power	Deepak Kumar Saxena
14	Bechtel India Private Limited	Ashish Bhatnagar
15	BHEL	S.V.N. Jithin Sundar
16	BHEL Corporate R & D	Mohana Rao Mandava
17	CBIP	V K Kanjlia
18	CG Power and Industrial Solutions Ltd	Vikrant Joshi
19	Consultant	Virendra Kumar Lakhiani
20	Consultant	N S Sodha
21	Consultant	N N Misra
22	Consultant	Venkata Chalapathi Chendur Venkatarao
23	Consultant	R P Sasmal
24	Consultant	Krishnan S. Balasubramanian

25	Consultant	Dhananjay Kumar Chaturvedi
26	Consultant	Sanjay Patki
27	Consultant	Pramod Rao
28	Consultant	Subhash Sethi
29	Consultant	S K Soonee
30	CPRI	Dr. Burjupati Nageshwar Rao
31	CPRI	Devender Rao Karre
32	CTR Manufacturing Industries Ltd.	T P Govindan
33	Damodar Valley Corporation	Abhijit Chakraborty
34	Damodar Valley Corporation	Anil Kumar Jha
35	DNV-KEMA	Ravi Kumar Puzhankara
36	DTL	Rajesh Kumar Arora
37	Energy Infratech Pvt. Ltd.	Madhuryya Prosad Chakravorty
38	ERDA	Satish Chetwani
39	Erode Sengunthar Engineering College	K. Singaram Christian Johnson
40	Free Lance	Hosalli Bhashyam Mukund
41	GE T&D India Ltd.	Mahesh Raman
42	GE T&D India Ltd.	Pandiyaraj Kalyani
43	GE T&D India Ltd.	Madhu Sudan
44	GE T&D India Ltd.	Santosh Kumar Annadurai
45	GE T&D India Ltd.	Santosh Kumar Annadurai
46	GETCO	Pankajbhai Suthar
47	GETCO	Nikunjkumar Makwana
48	GETCO	Ashokkumar J. Chavda
49	GETCO	Venu Birappa
50	GETCO	Sachin D Patel
51	GETCO	Nishant Priyakant Shah
52	GETCO	Jalpesh Trivedi
53	GETCO	Alpeshkumar Jayantilal Soni
54	GETCO	Zulfikarali M Vijapura
55	GETCO	Vinay Rathod
56	GETCO	Rajeshkumar Amrutlal Patel
57	GETCO	Bhasmang N. Trivedi
58	GETCO	Bhadreshkumar B. Mehta
59	GETCO	Nilesh Sheth
60	GETCO	Rameshchandra P. Satani
61	GETCO	Bankim Pravinchandra Soni
62	GETCO	Dipak kumar Patel
63	GETCO	Chetan G Thakkar
64	GETCO	Bhadresh B. Chauhan
65	GETCO	Yogesh Vishnu Joshi
66	Gujarat Industries Power Co. Ltd.	Rakesh Thakkar
67	Hindalco	Kaushik Tarafdar
68	IIT- Bangalore	Sudalai Shunmugam Sundaram
69	IIT-Bombay	Himanshu Bahirat
70	India Infrastructure Publishing Limited	Anchal Pahwa
71	Indian Institute of Science	Sarasij Das
72	Indian Institute of Science	Joy Thomas Meledath
73	Indian Institute of Science	Udaya Kumar
74	J&K Power Development Department	Habib Chowdhary
75	Kalpataru Power Trans. Ltd	Nitin Kumar Patel
76	Kalpataru Power Trans. Ltd	Pervinder Singh Chowdhry
77	Kalpataru Power Trans. Ltd	Milind Nene
78	KEC International Limited	Sunil Bhanot
79	KEC-RPG	E.V. Rao
80	KEI Industries Ltd	Lalit Sharma
81	Laxmi Associates	Aradhana Ray
82	M.P. Power Transmission Co. Ltd	K. Kamlesh Murty
83	Mahati Industries Pvt.Ltd.	Udaybabu Ratanchand Shah

84	Mahatma Gandhi Institute of Technology	Sheri Abhishek Reddy
85	Megawin Switchgear P. Ltd.	Muthuraj Ramaswamy
86	Modern Insulators Limited	Ram Kumar Vaithilingam
87	National Inst. of Technology Karnataka	I R Rao
88	North East Transmission Company	Harshal Maelwar
89	NTPC Ltd.	Nagesh Kondra
90	NTPC Ltd.	Subhash Thakur
91	Persotech Solutions	Pravinchandra Mehta
92	PFISTERER	Deepal Shah
93	Polycab Wires Pvt. Ltd.	Tony Martens
94	POSOCO	Subhendu Mukherjee
95	POSOCO	Santosh Kumar Jain
96	POSOCO	Shailendra Verma
97	POSOCO	K V S Baba
98	POSOCO	Vivek Pandey
99	POSOCO	Aditya Prasad Das
100	POSOCO	Rajiv Kumar Porwal
101	POSOCO	S.R. Narasimhan
102	POSOCO	Samir Chandra Saxena
103	POSOCO	Manoj Kumar Agarwal
104	POSOCO	Praveen Kumar Agarwal
105	POSOCO	Anamika Sharma
106	Power Grid	Anantha Sarma Boppudi
107	Power Grid	Brijendra Bahadur Singh
108	Power Grid	Subhash C Taneja
109	Power Grid	Gyaneshwar Payasi
110	Power Grid	Abhay Kumar
111	Power Grid	R P S Rana
112	Power Grid	Subir Sen
113	Power Grid	Ravindra Kumar Tyagi
114	Power Grid	Seema Gupta
115	Power Grid	Arun Kumar Mishra
116	Power Grid	B N De Bhowmick
117	Power Grid	Biswajit Bandhu Mukherjee
118	Power Grid	Rajesh Kumar
119	Power Grid	Anish Anand
120	Power Grid	Arbind Kumar Chaudary
121	Power Grid	Manish Kumar Tiwari
122	Power Grid	Nitesh Kumar
123	Power Grid	Dr. Sunita Chohan
124	Power Grid	K S Rathore
125	Power Grid	Rajeev Kumar Chauhan
126	Power Grid	Rashmi Pant Joshi
127	Power Grid	Chandra Kant
128	PRDC	Bapuji Palki
129	Primemeiden Limited	Vijayakumaran Moorkath
130	Protection Engg. & Research Laboratories	Pradeep Kumar Gangadharan
131	Raj Petro Specialities Pvt Ltd	Dr. Daya Shankar Shukla
132	Raj Petro Specialities Pvt Ltd	Sushil Chaudhari
133	Raj Petro Specialities Pvt. Limited	Baburao Keshawatkar
134	Rajasthan Test & Research Centre	Jaspaul Kalra
135	Raychem PRG Pvt. Ltd.	Subhankar Das
136	Raychem RPG Pvt. Ltd.	P. Kirushnaraj
137	Regen Powertech Private Limited	Vinod Kumar Agarwal
138	Reliance Power Transmission Ltd	Alok Roy
139	Shreem Electric Ltd.	Vikas Shahaji Jagadale
140	Silverline Electricals Pvt. Ltd.	Santosh Vishwakarma
141	SJVN Ltd.	Rashi Tyagi
142	SkipperSeil Ltd.	Surinder Kumar Negi
143	Sleepwalkers	Sivaji Burada
144	Sterlite Power	Gopal Ji

145	Sterlite Power Grid Ventures Ltd	Rajesh Suri
146	Sterlite Power Transmission Ltd.	Parantap Krishna Raha
147	Suzlon Power Infrastructure Ltd.	Naresh Kumar Panchal
148	Syselec Technologie Private Limited	Hrushaabh Prashaant Mishra
149	TAG Corporation	Vivek Thiruvenkatachari
150	Takalkar Powerr Engin & Consult. Pvt Ltd	Subhash Chandra Takalkar
151	Tata Consulting Engineers	Ashish Kumar Nandi
152	Taurus Powertronics Pvt. Ltd.	Narasimhan Ravinarayan Makaram
153	Technical Associates	Vishnu Agarwal
154	Telawne Cromptek Electricals Pvt. Ltd.	Yogesh Telawne
155	The Tata Power Co. Ltd.	Rajendra Vinayak Saraf
156	TS Transco	Arogya Raju Pudhota
157	Vision Vidyut Engineers Pvt. Ltd.	Jaywant Thorat
158	WAPCOS Ltd.	Hillol Biswas
159	Ziv Automation India Pvt Ltd	R C Anand

Organisational Members

Sl. No.	Organisation
1	ABB India Limited
2	Adani Electricity Mumbai Limited - Tran.
3	Adani Transmission Limited
4	APAR Industries Limited
5	Associated Power Structures Pvt. Ltd.
6	Atlanta Electricals Pvt.Ltd.
7	BAJAJ ELECTRICALS LTD.
8	Bharat Heavy Electricals Ltd. Bangalore
9	Bharat Heavy Electricals Ltd, Bhopal
10	Bharat Heavy Electricals Ltd, Haridwar
11	Bharat Heavy Electricals Ltd, Hyderabad
12	Bharat Heavy Electricals Ltd., Noida
13	Central Electricity Authority
14	Central Power Research Institute
15	CESC Limited
16	CTR Manufacturing Industries Ltd.
17	Delhi Metro Rail Corporation Ltd.
18	Easun-Mr Tap Changers (P) Limited
19	Gupta Power Infrastructure Limited
20	India Smart Grid Forum (ISGF)
21	Karmatara Engineering Pvt. Ltd.
22	KEI Industries Ltd.
23	Larsen & Toubro Limited- Construction
24	LS Cable India Pvt. Ltd.
25	National High Power Test Lab. Pvt. Ltd.
26	NHDC Limited
27	NHPC Limited
28	NLC India Limited
29	North Eastern Electric Power Corp. Ltd
30	NTPC - Dadri SSTP
31	NTPC Limited - Koldam
32	NTPC Limited- Faridabad
33	NTPC Limited, Anta GPS
34	NTPC Limited, Auraiya
35	NTPC Limited, BARH
36	NTPC Limited, Bongaigaon TPP
37	NTPC Limited, H.Q.
38	NTPC Limited, Jhanor
39	NTPC Limited, Kahalgaon STPS
40	NTPC Limited, Kawas GPP
41	NTPC Limited, Kayamkulam
42	NTPC Limited, Korba STPS
43	NTPC Limited, Mouda STPP
44	NTPC Limited, Ramagundam STPS
45	NTPC Limited, Rihand STPP
46	NTPC Limited, Simhadri STPP
47	NTPC Limited, Singrauli STPS
48	NTPC Limited, SIPAT STPS
49	NTPC Limited, Talcher STPS
50	NTPC Limited, Tanda
51	NTPC Limited, Vindhyachal STPS

52	NTPC Limited,Farakka STPS
53	NTPC Ltd.-Kudgi STPS
54	NTPC Sail Power Co. Pvt. Ltd.
55	Olectra Greentech Ltd.
56	ONGC Tripura Power Company Ltd.
57	Polycab Wires Pvt. Ltd.
58	POSOCO- ERLDC
59	POSOCO- H.Q.
60	POSOCO- SRLDC
61	POSOCO- WRLDC
62	POSOCO-NERLDC
63	Power Research & Develop. Cons. Pvt. Ltd
64	Powergrid Corp. of India Limited, WR-II
65	Powergrid Corp. of India Limited, Patna
66	Powergrid Corp. of India Ltd, Bangaluru
67	Powergrid Corp. of India Ltd, Kolkata
68	Powergrid Corp. of India Ltd, Lucknow
69	Powergrid Corp. of India Ltd, Secunderabad
70	Powergrid Corp. of India Ltd, Shillong
71	Powergrid Corp. of India Ltd.,Jammu
72	Powergrid Corp. of India Ltd., Maharashtra
73	Powergrid Corp. of India Ltd., Bangalore
74	Powergrid Corp. of India Ltd-NRT-I
75	Powergrid Corp. of India Ltd-Orissa
76	Powergrid Corporation of India, H.Q.
77	R.S. Infraprojects Pvt. Ltd.
78	Savita Oil Technologies Ltd.
79	Scope T&M Pvt Ltd
80	Siemens Ltd, EM TS
81	SJVN Limited
82	Sterlite Power Transmission Limited
83	Supreme & Co. Pvt. Ltd.
84	Tata Power Delhi Distribution Limited
85	Taurus Powertronics Pvt. Ltd
86	Techno Electric and Engineering Co. Ltd.
87	THDCIL
88	The Motwane Manufacturing Co. Pvt Ltd.
89	The Tata Power Company Ltd.
90	Toshiba Trans.& Dist. Systems (I) Pvt Ltd.
91	Transformers & Rectifier (India) Ltd.
92	Transmission Corporation of Telangana Limited
93	Transrail Lighting Limited
94	Universal Cables Limited

Young Members

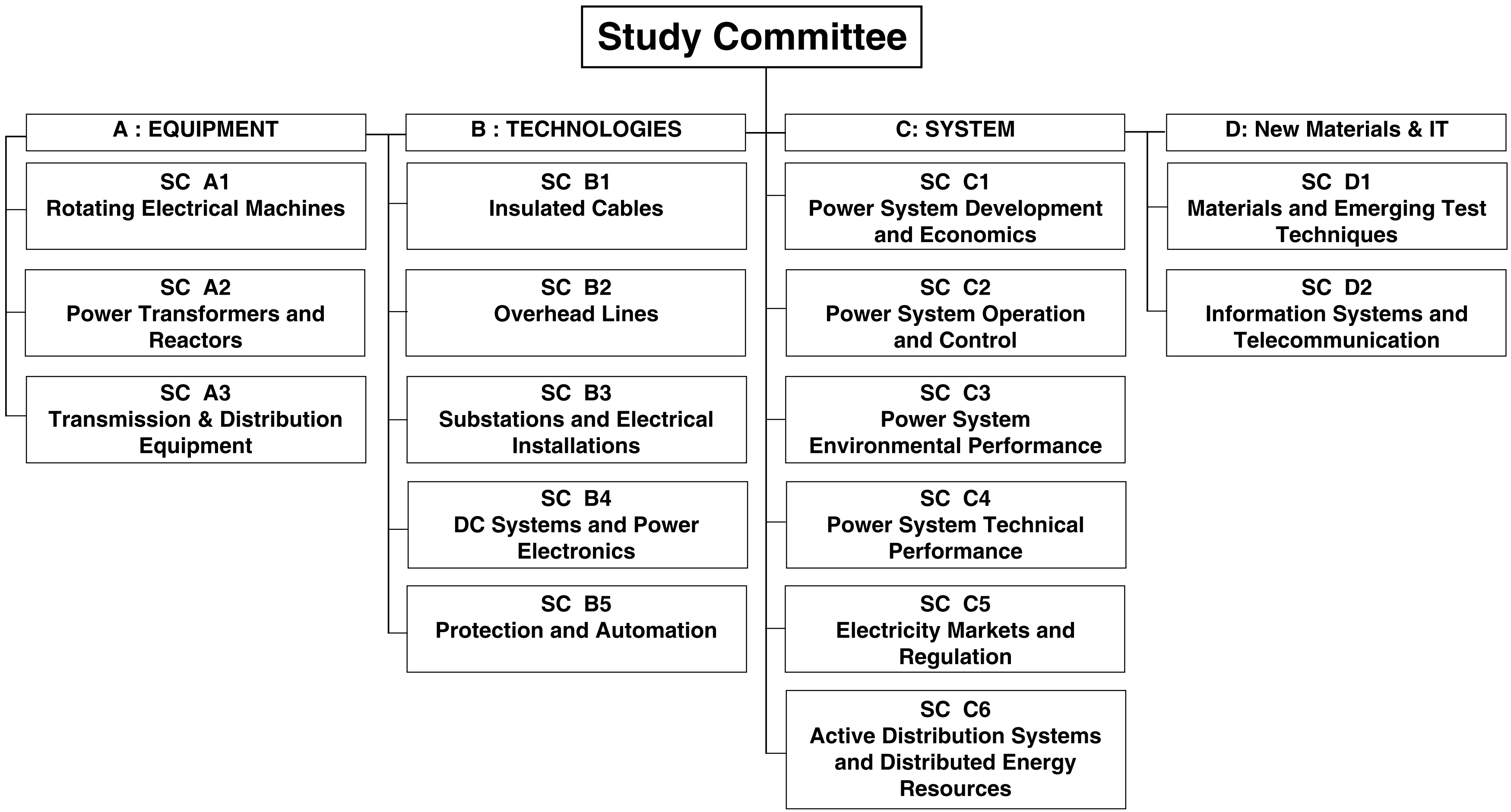
S.No.	Name	Organistaion
1	Animesh Moji	Adani Group
2	Mohan Vadivel	GE T&D India Ltd.
3	Aishwarya Dixit	Hyosung T&D India Pvt. Ltd.
4	Kummaragu K	Indotech Transformer Ltd.
5	Dony C S	Kerala State Electricity Board Ltd.
6	Atma Ram Gupta	NIT Kurukshetra
7	Harshvardhan Senghani	NTPC Ltd.
8	Gourav Mukherjee	POSOCO
9	Ankit Gupta	POSOCO
10	Saibal Ghosh	POSOCO
11	Dwaipayan Sen	Power Grid
12	Manash Jyoti Baishya	Power Grid
13	Ankur Kumar	Power Grid
14	Jeetesh Kumar	Power Grid
15	Amit Kuma	Power Grid
16	Lokesh Kumar Singh Chundawat	Power Grid
17	Amandeep Singh	Power Grid
18	Ankit Prakash Vaishnao	Power Grid
19	Madhav Beni	Power Grid
20	Priyanka Swain	Tata Consulting Engineers Limited

Student Members

S. No.	Organisation	Name
1	Indian Institute of Technology Kanpur	Anamika Dubey
2	Indian Institute of Technology Kanpur	J G sreenath
3	Indian Institute of Technology Kanpur	Aasim
4	Indian Institute of Technology Kanpur	Akhilesh Prakash Gupta
5	Indian Institute of Technology Kanpur	Vineeth V
6	Indian Institute of Technology Kanpur	Piyush Warhad Pande
7	Indian Institute of Technology Kanpur	P. Naga Yasasvi
8	Indian Institute of Technology Kanpur	Gaurav Khare
9	Indian Institute of Technology Kanpur	Priyanka Gangwar
10	Indian Institute of Technology Kanpur	Saurabh Kesherwani
11	Indian Institute of Technology Kanpur	Ankit Yadav
12	Indian Institute of Technology Kanpur	Avinash kumar
13	Indian Institute of Technology Kanpur	Rajarshi Dutta
14	Indian Institute of Technology Kanpur	Syed Mohammad Ashraf
15	Indian Institute of Technology Kanpur	Arindam Mitra
16	Indian Institute of Technology Kanpur	Bandopant Pawar
17	Indian Institute of Technology Kanpur	Anamika Tiwari
18	National Institute of Technology, Calicut	Amararapu Satish
19	National Institute of Technology, Calicut	Aswin Bhaskar P E
20	National Institute of Technology, Calicut	Cheemala Vaishnavi
21	National Institute of Technology, Calicut	Divya P
22	National Institute of Technology, Calicut	K Vamsi Krishna
23	National Institute of Technology, Calicut	Sarov Mohan S
24	National Institute of Technology, Calicut	Thalluri Chaitanya Sai
25	National Institute of Technology, Calicut	Vipul Kumar
26	National Institute of Technology, Calicut	Avinash Nelson
27	National Institute of Technology, Calicut	Gowrishankar S
28	National Institute of Technology, Calicut	Joyce Jacob
29	National Institute of Technology, Calicut	Emil Ninan Skariah
30	National Institute of Technology, Calicut	Jacob P Varghese
31	National Institute of Technology, Calicut	Lakshmi Tharamal
32	National Institute of Technology, Calicut	Anjitha V
33	National Institute of Technology, Calicut	Haritha G
34	National Institute of Technology, Calicut	Ravishankar A N
35	National Institute of Technology, Calicut	Athira Raju
36	National Institute of Technology, Calicut	Subin Koshy
37	National Institute of Technology, Calicut	Rahul S
38	National Institute of Technology, Calicut	Rinsha V
39	National Institute of Technology, Calicut	T S Bheemraj
40	National Institute of Technology, Calicut	Sanila P
41	National Institute of Technology, Calicut	Najda V M
42	National Institute of Technology, Calicut	Renuka V S
43	Indian Institute of Technology Bombay	Lokesh Kumar Dewangan
44	Indian Institute of Technology Bombay	Vatsal Kedia
45	Indian Institute of Technology Bombay	Santanu Paul

46	Indian Institute of Technology Bombay	Siba Kumar Patro
47	Indian Institute of Technology Bombay	Aditya Nadkarni
48	Indian Institute of Technology Bombay	Kaustav Dey
49	Indian Institute of Technology Bombay	Santosh V Singh
50	Indian Institute of Technology Bombay	Kavita Kiran Prasad
51	Indian Institute of Technology Bombay	Anees V P
52	Indian Institute of Technology Bombay	soumya Ranjan mohapatra
53	Indian Institute of Technology Bombay	Kevin Gajjar
54	Indian Institute of Technology Bombay	Rohit Thute
55	Indian Institute of Technology Bombay	B. Sai Ram
56	Indian Institute of Technology Bombay	Minal Chougule
57	Indian Institute of Technology Bombay	Soumya Kanta Panda
58	Indian Institute of Technology Bombay	Joel Jose
59	Indian Institute of Technology Bombay	Hemantkumar Goklani
60	Indian Institute of Technology Bombay	vinay chindu
61	Indian Institute of Technology Bombay	Gopakumar
62	Indian Institute of Technology Bombay	Patil Nikhil Suresh
63	Indian Institute of Technology Bombay	Pragati Gupta
64	Indian Institute of Technology Bombay	Suman Kumar Neogi
65	Indian Institute of Technology Bombay	Ajith J
66	Indian Institute of Technology Bombay	Makarand M Kane
67	Indian Institute of Technology Bombay	Annoy Kumar Das
68	Manipal University Dahmi Kalan Jaipur	Udayan Atreya

Four Group of CIGRE Study Committees



FIELDS OF ACTIVITY OF CIGRE STUDY COMMITTEES

Study Committees No.	Scope
A1	**Rotating Electrical Machines** : The SC is focused on the development of new technologies and the international exchange of information and knowledge in the field of rotating electrical machines, to add value to this information and knowledge by means of synthesizing state-of-the-art practices and developing guidelines and recommendations.
A2	**Power Transformers and Reactors** : The scope of SC A2 covers the whole life cycle of all kind of power transformers, including HVDC transformers, phase shifters, shunt reactors and all transformer components as bushing and tap-changers.
A3	**Transmission & Distribution Equipment** : The scope of the SC A3 covers theory, design, construction and operation for all devices for switching, interrupting and limiting currents, surges arresters, capacitors, busbars, equipment insulators and instrument transformers used in transmission and distribution systems.
B1	**Insulated Cables** : The scope of SC B1 covers the whole Life Cycle of AC and DC Insulated cables for Land and Submarine Power Transmission, which means theory, design, applications, manufacture, installation, testing, operation, maintenance, upgrading and uprating, diagnostics techniques. It has been focused on HV & EHV applications for a long time. Nowadays MV applications are more and more taken into consideration.
B2	**Overhead Lines** : The scope of the Study Committee SC B2 covers all aspects of the design and refurbishment of overhead power lines. The Study Committee's strategic goals include: increased acceptance of overhead lines; increased utilization of existing overhead lines; improved reliability and availability of overhead lines.
B3	**Substations and Electrical Installations** : The scope of work for SC B3 includes the design, construction, maintenance and ongoing management of transmission and distribution substations, and the electrical installations in power stations, but excluding generators.
B4	**DC Systems and Power Electronics** : The scope of SC B4 covers High Voltage Direct Current systems and Power Electronics for AC networks and Power Quality improvement. Overhead lines or cables, which may be used in HVDC systems are not included in the scope, but are the responsibility of SC B2 and SC B1 respectively. The members of B4 come from Manufacturers, Utilities, transmission system operators (TSOs), Consultants and Research Institutes. SC B4 is active in recruiting young engineers to participate in its activities.
B5	**Protection and Automation** : The scope of the Committee covers the principles, design, application and management of power system protection, substation control, automation, monitoring, recording and metering – including associated internal and external communications and interfacing for remote control and monitoring.
C1	**Power System Development and Economics** : The SC's work includes issues, methods and tools related to the development and economics of power systems, including the drivers to: invest in expanding power networks and sustaining existing assets, increase power transfer capability, integrate distributed and renewable resources, manage increased horizontal and vertical interconnection, and maintain acceptable reliability in a cost-efficient manner. The SC aims to support planners to anticipate and manage change.
C2	**Power System Operation and Control** : The scope of the SC C2 covers the technical, human resource and institutional aspects and conditions needed for a secure and economic operation of existing power systems under security requirements against system disintegration, equipment damages and human injuries.
C3	**Power System Environmental Performance** : The scope of this Study Committee is focused on the identification and assessment of electric power systems environmental impacts and the methods used for assessing and managing these impacts during the all life cycle on the power system assets.
C4	**Power System Technical Performance** : The scope of SC C4 covers system technical performance phenomena that range from nanoseconds to many hours. SC C4 has been engaged in the following topics: Power Quality, EMC/EMI, Insulation Coordination, Lightning, and Power systems performance models and numerical analysis.
C5	**Electricity Markets and Regulation** : The scope of the Study Committee is "to analyze the different market approaches and solutions and their impact on the electric supply industry in support of the traditional economists, planners and operators within the industry as well as the new actors such as regulators, traders, technology innovators and Independent Power producers.
C6	**Active Distribution Systems and Distributed Energy Resources** : SC C6 facilitates and promotes the progress of engineering, and the international exchange of information and knowledge in the field of distributions systems and dispersed generation. The experts contributes to the international exchange of information and knowledge by the rizing state of the art practices and developing recommendations.
D1	**Materials and Emerging Test Techniques** : The scope of Study Committee D1 covers new and existing materials for electrotechnology, diagnostic techniques and related knowledge rules, as well as emerging test techniques with expected impact on power systems in the medium to long term.
D2	**Information Systems and Telecommunication** : The scope of this SC is focused on the fields of information systems and telecommunications for power systems. SC D2 contributes to the international exchange of information and knowledge, adding value by means of synthesizing state of the art practices and drafting recommendations.

HIGHLIGHTS OF POWER SECTOR

GROWTH OF INSTALLED CAPACITY

(Figures in MW)

	At the end of 12th Plan (March 2017)	As on 30.11.2019
THERMAL	218330.00	229401.42
HYDRO	44478.00	45399.22
NUCLEAR	6780.00	6780.00
RENEWABLE ENERGY SOURCES	57244.00	84399.90
TOTAL	**326832.00**	**365980.54**

Source : CEA

ALL INDIA REGION WISE INSTALLED CAPACITY

As on 30-11-2019

(Figures in MW)

Region	Thermal	Nuclear	Hydro	RES	Total
Northern	58173.23	1620	19707.77	16392.62	95893.62
Western	85900.11	1840	7547.50	25085.15	120372.76
Southern	53089.34	3320	11774.83	41051.86	109236.03
Eastern	29616.87	0	4942.12	1488.68	36047.67
N. Eastern	2581.83	0	1427.00	363.41	4372.23
Islands	40.05	0	0.00	18.19	58.24
All India	**229401.42**	**6780**	**45399.22**	**84399.90**	**365980.54**
Percentage	**62.68**	**01.85**	**12.40**	**23.06**	**100**

Source : CEA

SECTOR WISE INSTALLED CAPACITY AND GENERATION

As on 30-11-2019

Sector	Installed Capacity (MW)					Percentage Share	Net Capacity added
	Thermal	Nuclear	Hydro	RES	Total		During Nov. 2019
STATE	74506.21	0.00	26958.50	2350.43	103815.14	28.37	0 MW
PRIVATE	86857.30	0.00	3394.00	80417.17	170668.47	46.63	
CENTRAL	68037.91	6780.00	15046.72	1632.30	91496.93	25.00	
TOTAL	**229401.42**	**6780.00**	**45399.22**	**84399.90**	**365980.54**	**100**	

Source : CEA

GROWTH OF TRANSMISSION SECTOR

	Unit	At the end of 12th Plan (March 2017)	As on Nov. 2019	Addition after 12th Plan (2017-22) (up to Nov. 2019)
TRANSMISSION LINES				
HVDC	ckm	15556	15556	52639
765 kV	ckm	31240	42804	
400 kV	ckm	157787	183304	
220 kV	ckm	163268	178826	
Total Transmission Lines	**ckm**	**367851**	**420490**	**52639**
SUBSTATIONS				
HVDC	MW	19500	22500	209158
765 kV	MVA	167500	223500	
400 kV	MVA	240807	335957	
220 kV	MVA	312958	366466	
TOTAL	**MW/ MVA**	**740765**	**949923**	**209158**

RURAL ELECTRIFICATION / PER CAPITA CONSUMPTION

Total no. of Villages	597464
No. of Villages Electrified	597464
% of Villages Electrified	100.00
No. of Pump-sets Energized (At the end of 12th Plan)	21212860
Per Capita Consumption during 2018-19*	1181 kWh

**Provisional*

RE SECTOR IN INDIA: POTENTIAL AND ACHIEVEMENTS

Sector GRID-INTERACTIVE POWER (CAPACITIES in MWp)	FY 2019-20 Target (MW)	FY 2019-20 Achievement (April-Oct. 2019)	Cumulative Achievements (MW) (as on 31.10.2019)
Wind	3000.00	1464.06	37090.02
Solar Power (SPV)	8500.00	3515.59	31696.24
Small Hydro (up to 25 MW)	50.00	53.95	4647.10
Bio Power (Biomass & Gasification and Bagasse Cogeneration)	250.00	28.00	9806.31
Waste to Power	2.00	1.50	139.80
Total (Approx)	**11802.00**	**5063.10**	**83379.47**
OFF GRID/CAPTIVE POWER (CAPACITIES IN MW_{EQ})	**411.00**	**34.57**	**1292.27**
Other Renewable Energy Systems (Biogass plants) (capacity in Nos.)	**0.76**	**0.06**	**50.33**

Source : MNRE

*progress upto June 2019

NEWS

POWER DISTRIBUTION SECTOR NEEDS DRASTIC REFORMS: POWER SECY

Power secretary Subhash Chandra Garg on said there is a need to bring in drastic reforms in the power distribution sector after the failure of the first version of Ujwal Discom Assurance Yojna (UDAY) and unable to fully address industry woes.

Addressing an event here organised by IEEMA, Garg said the government is working on the revised version of the scheme, where it will also cater to separating carriage and content in the distribution sector.

“Electricity distribution is an area of concern. There have been various initiatives taken by the government, including the UDAY scheme to revive the distribution sector, but it has not proved to be effective. It is necessary that we take drastic reforms in the sector,” Garg said.

He further said the government is currently working on bringing in the revised version of the scheme UDAY 2 which seeks to address most of the issues of the sector.

“The aim of the UDAY scheme was to make sure that power is paid for. I am of the view that is discoms are buying power, they should pay. Under the UDAY scheme, states have to bear the burden of the losses of discoms. If this time the power sector digs deep holes in the finances of the state, then Centre will have to take the burden as the discoms will not be able to do it,” Garg added.

He also noted that the private sector will play a key role in the transformation journey of the Indian power industry.

Source : PTI, Sep 17, 2019

INDIA HAS TARGETED A TOTAL HYDEL POWER GENERATION CAPACITY ADDITION OF 1,190 MW DURING THE YEAR

India has emerged the top country in the Asia-Pacific region for hydro technology tenders recorded during the quarter ended June 2019, with 24 tenders and a 42.9% share followed by Nepal at 18 tenders and a 32.1% share. During the period 56 tenders were announced marking a drop of 34% over the last four-quarter, against an average of 85, according to GlobalData’s power industry tenders database.

Supply & erection tenders were 20 in number with a 35.7% share, while repair, maintenance & upgrade were 15 in number with a 26.8% share in the total number of tenders in the Asia-Pacific region. Consulting & similar services saw 15 tenders issued during the quarter which comprised 26.8% share. Project implementation tenders were six in number with a 10.7% share.

India has targeted a total hydel power generation capacity addition of 1,190 MW during the year. If achieved, India’s hydel capacity will cross 50 GW and touch 51.18 GW this year. At present large hydel capacity stands at around 45,399 MW while small hydel is around 4594 MW totaling 49.99 GW. Last year the government had targeted hydel capacity addition of 840 MW but it managed to achieve only 140 MW.

According to plans, this year central sector NEEPCO will be adding the highest capacity of 600 MW at Kameng Hydel Power project in Arunachal Pradesh. State government of Himachal Pradesh will be adding another 211 MW in the state. These would include three units of 33.33 MW by state government-owned BVPCL and three units of 37 MW by Himachal Pradesh Power Corporation Ltd.

Three private sector companies are also scheduled to add around 379 MW. These are GMR’s Bajoli Holi project in Himachal Pradesh with a total capacity of 3 x 60 MW, L&T’s Singoli Bhatwari project in Uttarakhand with a total capacity of 2 x 33 MW and Sorang hydel project with proposed capacity of 2 x 50 MW at Uttarakhand.

According to the schedule prepared by Central Electricity Authority, the country is likely to cross the 50 GW installed capacity mark this month if NEEPCO manages to commission its proposed unit 1 and 2 of the Kameng project. These are to have a generation capacity of 150 MW each and are scheduled to be commissioned this month. It is slated to start commercial operation in August.

Last year, hydel power plants achieved a 7% year-on-year growth in power generation at 135 billion units. It contributed 10% of the total power generation for the year among conventional power generation sources.

At present, the largest hydel generation capacity is in north India at 19.7 GW followed by South at 11.77 GW. Western India has a total installed capacity of around 7.55 GW followed by East at 4.94 GW.

Source : ET Bureau, Sep 25, 2019

CESC DROPS PLANS TO SEPARATE DISTRIBUTION AND GENERATION BIZ

In the filing, CESC said that in continuation of its intimation dated 12 October 2018, informing shareholders that the scheme was made effective from 1 October 2017, except demerger of the generation undertaking of the company into Haldia Energy L...

Kolkata-based power generation and distribution company CESCNSE 0.28% will no longer pursue its plan to separate generation and distribution businesses, it has informed in a stock market filing. In the filing, CESC said that in continuation of its intimation dated 12 October 2018, informing shareholders that the scheme was made effective from 1 October 2017, except demerger of the generation undertaking of the company into Haldia Energy Ltd, a wholly-owned CESC subsidiary.

"The Board of Directors, at its meeting held on Thursday, inter alia, discussed the present status of the demerger and decided that it would be prudent and in the best interest of the company, its shareholders and other stakeholders to no longer pursue the said Demerger. The company will make the necessary application to the Kolkata bench of the National Company Law Tribunal in this regard. We request you to kindly take this on record," CESC said in its filings to the exchange.

Last year, the company had announced that CESC would be demerged into three entities. Power and retail would be separate companies while IT, FMCG and Quest Mall will be brought under another company. The plan was to demerge distribution and generation of CESC at a later stage. It had applied West Bengal power regulators' permission for demerging these two companies and signing of a power purchase agreement between the two. Other power business like Haldia Energy Ltd and Dhariwal Infrastructure, it's solar, hydel and power distribution businesses in other states continued to remain subsidiaries of CESC.

CESC had already received NCLT's order for four-way demerger. However, it divided the company into three as it needed state power regulator's approval for separating its power distribution and generation business. According to sources, the West Bengal Power Regulator had reservations with respect to the demerger of distribution and the generation business since the division of

assets was an issue. Eventually, CESC abandoned the plan which it announced on Thursday after its board meeting.

Source : ET Bureau, Nov 14, 2019

INDIA, BANGLADESH GIVES IMPETUS TO CROSS-BORDER ENERGY CORRIDOR

The 2nd Project Review Monitoring Committee (PRMC) meeting for the India-Bangladesh Friendship Pipeline project was successfully held between both the countries here on Thursday in what can be viewed as a concrete step in cross border connectivity corridor.

The meeting was held in the atmosphere of great cordiality and warmth notwithstanding recent controversy over Citizenship Amendment Bill, officials said.

Both countries reiterated the strong commitment and high priority attached to this bilateral relationship, and agreed to extend full cooperation on this project, in view of the centrality of cross-border energy cooperation in our bilateral partnership, according to officials.

The Rs. 346 crore, 130-kilometre India-Bangladesh Friendship Pipeline Project is a landmark project being undertaken under the grant assistance from India to Bangladesh.

The pipeline will connect Siliguri in West Bengal in India and Parbatipur in Dinajpur district of Bangladesh. The oil pipeline will supply high speed diesel to Bangladesh from Numaligarh refinery.

Source : ET Bureau, Dec 19, 2019

SINGAPORE'S SEMBCORP TO BUYOUT BALANCE STAKE IN INDIA JV FOR RS 406 CRORE FROM GAYATRI PROJECTS

Singapore-headquartered Sembcorp Industries is in pact to buyout its Indian partner, Gayatri ProjectsNSE 0.06 %' 5.95% stake in Sembcorp Energy India (SEIL) for Rs 406 crore, the two companies said on Wednesday.

On completion of this transaction, Sembcorp Energy India will become a wholly owned subsidiary of the parent.

"The proposed acquisition will allow Sembcorp to have the flexibility as sole owner to evaluate and pursue a full range of growth opportunities in the renewables segment, while at the same time seeking the right equity window to list its India business or to pursue other capital recycling options," the company said.

In a separate statement, the debt-laden Gayatri Projects, which has been struggling to meet its debt obligations, said, "The proceeds of the stake sale will be utilised for reduction of the debt, general corporate purposes and working capital."

The proposed acquisition is expected to be completed by the end of the year, subject to the satisfaction of certain conditions precedent, including shareholders' approval of Gayatri Projects.

As per the deal, there is also potential future earn-outs for Gayatri Projects on achievement of certain milestones by SEIL. Sembcorp said it will fund the deal through a mix of internal funds and borrowings.

SEIL, is an independent power producer which has a diversified portfolio of thermal and renewable energy assets of more than 4,300 megawatts (mw).

Source : ET Bureau, Dec 05, 2019

WIND WOES INCREASE IN INDIA, WORLD'S CHEAPEST MARKET, AS DELAYS PILE UP THREATENING NATION'S RENEWABLE-ENERGY AMBITIONS

About 2 gigawatts of wind power generation auctioned by the federal government since February 2017 is running behind schedule, according to BloombergNEF. That number has more than quadrupled since February, threatening to derail the nation's renewable-energy ambitions.

Developers are having difficulty finding affordable land, getting financing and connecting to grids after accepting some of the world's lowest green energy tariffs over the past two and a half years. On top of that hangs the uncertainty whether they will be paid on time by power distribution companies, known locally as discoms.

"With such low tariffs, projects can be viable only if they have access to low-cost funds, cheap land and inexpensive transmission infrastructure. Unfortunately all these three are found wanting for most wind projects," said Prashant Khankhoje, a director at India Electron Exchange, a New Delhi-based power consulting firm. "The risk of delayed payments from discoms is another big issue, which makes lenders scared to lend to wind projects."

Adani Green EnergyNSE 0.63 % Ltd., Torrent PowerNSE 3.81 % Ltd. and Renew Power Ltd. are among companies that have missed the targets. The three companies and the Renewable Energy Ministry didn't respond to emails seeking comment.

India started auctioning wind projects in 2017, ditching a previous system that had feed-in tariffs for developers. The auctions saw aggressive bidding from developers, which led to a drop in prices.

The need to keep costs down amid the increasing competition also led to financial difficulties at some turbine makers, such as SuzlonNSE 0.00 % Energy Ltd., impeding their ability to execute projects on time.

"Today we're left with a handful of equipment suppliers, which has turned the industry from a buyers' market to a sellers' market," said Vinay Rustagi, managing director at Bridge To India, a consultant to the renewables industry. "Developers have lost the bargaining leverage they need to make the project viable."

Prime Minister Narendra Modi set a target in 2014 to install 175 gigawatts of renewable energy capacity by 2022. As the nation approaches that goal, Modi this year announced a longer-term plan to install 450 gigawatts of renewable capacity as part of the country's efforts to reduce the emissions intensity of its economy.

"That target looks extremely, extremely ambitious," said Rustagi. "Until core issues of site availability, adherence to contracts and timely payments by discoms are resolved, developers would be wary of investing."

International Council on Large Electric Systems (CIGRE)

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International Council on Large Electric Systems (CIGRE), 21 Rue d'Artois, 75008 Paris, France
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Email of Secretary General: philippe.adam@cigre.org

Date of inception : CIGRE was founded in 1921 with its HQ at PARIS

Aims and Objectives:

CIGRE (International Council on Large Electric Systems) is one of the leading worldwide Organizations on Electric Power Systems, covering their technical, economic, environmental, organisational and regulatory aspects.

A permanent, non-governmental and non-profit International Association, based in France, CIGRE was founded in 1921 and aims to:

- Facilitate the exchange of information between engineering personnel and specialists in all countries and develop knowledge in power systems.
- Add value to the knowledge and information exchanged by synthesizing state-of-the-art world practices.
- Make managers, decision-makers and regulators aware of the synthesis of CIGRE's work, in the area of electric power.

More specifically, issues related to planning and operation of power systems, as well as design, construction, maintenance and disposal of HV equipment and plants are at the core of CIGRE's mission. Problems related to protection of power systems, telecontrol, telecommunication equipment and information systems are also part of CIGRE's area of concern.

Establishment of Indian Chapters:

CIGRE India was set up as society on 24.07.91 with CBIP as secretariat.

Membership:

(I) Collective Members (I) - (companies of industrial and commercial nature)

(II) Collective Members (II) - (Universities, Engineering Colleges,Technical Institutes and regulatory commission)

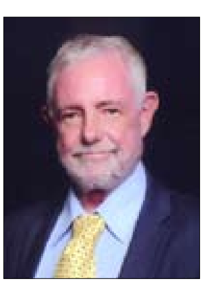
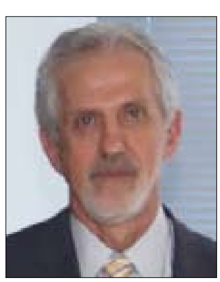
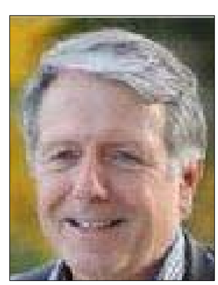
(III) Individual Members -

(In the engineering, teaching or research professions as well as of other professions involved in the industry (Lawyers, economists, regulators...)

(IV) Young Members (Below 35 Years of Age) -

(In the engineering, teaching or research professions as well as of other professions involved in the industry (Lawyers, economists, regulators...)

CIGRE - HQ

President	Chairman TC	Treasurer	Secretary General
Rob STEPHEN (SA)	Marcio SZECHTMAN (BR)	Michel AUGONNET (FR)	Philippe ADAM (FR)
			

INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

TO BE SENT TO NATIONAL COMMITTEE (i.e Central Board of Irrigation and Power)

MEMBERSHIP APPLICATION FORM – for the year 2020

Please fill in the column of the relevant MEMBER CATEGORY.

MEMBERSHIP RENEWAL ☐ **NEW MEMBERSHIP** ☐ **Membership Number** ☐

☐ ***INDIVIDUAL MEMBER I*** ☐ ***INDIVIDUAL MEMBER II*** *(Young Member under 35 years)*	***COLLECTIVE MEMBER I*** *Administrative bodies, scientific and technical organisations, research institutes, public or private Companies industrial and/or commercial.*	***COLLECTIVE MEMBER II*** *Universities, Educational Bodies only.*
Family Name .... Forename .... Position, Dept. .... Company, Organisation .... Full Address .... TEL .... Mobile no. .... FAX .... E-Mail.......... Year of Birth	NAME of COMPANY .... Person or Department to receive ELECTRA journal. .... Full Address .... TEL .... Mobile no. .... FAX .... E-Mail..........	NAME of UNIVERSITY .... Person or Department to receive ELECTRA journal . ... Full Address .... TEL .... Mobile no. .... FAX .... E-Mail..........

S.no	Category	Fees	Fee incuding GST 18% to be paid
1	Collective I	Rs. 65,000/-	Rs. 76,700/-
2	Collective II (Universities & Regulatory Com.)	Rs. 25,000/-	Rs. 29,500/-
3	Individual	Rs. 7,500/-	Rs. 8,850/-
4	Young - below 35 years of age	Rs. 3,750/-	Rs. 4,425/-

Fee can be paid through cheque/ DD in favour of CIGRE India or through bank transfer

Vender Name	THE COMMITTEE FOR THE INTL CONF ON LHVES		
Bank Name & Branch	Canara Bank/Delhi Diplomate Enclave		
Branch Address	16/48, Malcha Marg Shopping Centre, Chankyapuri, New Delhi -110021. Ph.No.41680133-34-35		
IFSC code of branch	ICIC0000346	**MICR No.** : 110229052	**Account No.** : 034601001054
Type of account	Special Saving Account		**PAN No.** : **AAAAZ0260A** **GSTIN : 07AAAAZ0260A1Z1**

For information pl contact – Vishan Dutt, CIGRE India, CBIP Building, Malcha Marg, Chanakyapuri, New delhi – 110 021 : Mobile – 9811431554 ; vishandutt@cbip.org